Ecosystem Health

Introduction

An ecosystem is an interdependent grouping of living and non-living components in the environment. Ecosystems are defined by the interactions between living organisms, including humans, and their physical environment. All ecosystems are subjected to both natural stressors such as fire, flooding, and wind, and human-induced stressors such as habitat modification and exposure to hazardous wastes and chemicals. On a routine basis, chemical, physical and biological stressors challenge the integrity of ecosystems. Typically, ecosystems can rebound from these stressors. However, if an ecosystem loses a key structural component, the application of another stressor may set off a chain of events that leads to the degradation or potential destruction of the ecosystem. Structural and functional integrity are key factors in the maintenance of viable ecosystems.

In California, the most populous state in the nation, the primary human-related stressors on our ecosystems emanate from modifications of the state's land and water resources. Prime examples include changes in water temperature and flow; habitat quality, quantity and fragmentation; and the release of contaminants from urban and agricultural areas.

Ecosystem Health Indicator

Land cover and management & threatened and endangered species

Land cover

Land cover of major terrestrial ecosystems in California (Type I)

Land management

Land management in California (Type I)

Threatened and endangered species

California threatened and endangered species (Type I)

Health of aquatic and coastal ecosystems

Aquatic life protection and biodiversity

Status of Central Valley chinook salmon populations (Type I)

California least tern populations (Type I)

Persistent organic pollutants in harbor seals (Type III)

Habitat and water quality protection

Clarity of Lake Tahoe (Type I)

Stream bioassessment - invertebrate populations (Type II)

Endocrine-disrupting chemicals in aquatic ecosystems (Type III)

Desert ecosystem health

Alteration in biological communities

Status of the desert tortoise population (Type I)

Habitat degradation

Impacts of off-highway vehicles on the desert (Type II)

Distribution of exotic plants (Type III)

Health of forests, shrub land, and grassland (terrestrial) ecosystems

Habitat quality and quantity

Change in habitat quantity in rangelands and forests (Type I)

Change in forest canopy (Type I)

Pest and disease related mortality in forests (Type I)

Wildfires in forests and grasslands (Type I)

Sustainability of California's forests (Type I)

Loss of biodiversity

Status of northern spotted owl (Type II)

Status of amphibian populations (Type III)

Ozone injury to pine needles (Type III)

Agroecosystem health

Availability of natural resources

Conversion of farmland into urban and other uses (Type I)

Soil salinity (Type II)

Positive and negative environmental impacts

Urban ecosystems

Urban tree canopy (Type III)

Issue 1: Overarching Issues: Land Cover and Management & Threatened and Endangered Species

Underlying any issue related to ecological integrity in California are the issues of the extent and status of ecosystems and threatened and endangered species. The ability to protect important plant and animal habitats and biodiversity begins with knowledge of the geographical distribution of different ecosystems and the way in which these lands are being used.

Sub-issue 1.1: Land cover

Land cover is a general measurement of the abundance of ecosystems. It tracks the total area of both natural ecosystems (forests, grasslands, wetlands, etc.) and transformed ecosystems such as irrigated agriculture, dense urban areas, and development in rural areas. Knowledge of land cover permits an analysis of the change in the extent of the various ecosystems over time, and thus can provide a general measurement of ecosystem health and viability. Land cover measurements help define the broadest categories of natural versus altered ecosystems.

Indicator

Land cover of major terrestrial ecosystems in California (Type I)

Sub-issue 1.2: Land management

How land is managed within the broad land cover types also influences ecological health. The greatest ecological impacts caused by humans result from land management decisions. As land managers and landowners change their management objectives, lands that formerly had minimum human impact can be subjected to ecosystem-disturbing activities. These activities include replacing natural biological communities with agricultural systems, introducing hydrologic or chemical cycle alterations, and changing the earth's surface by creating urban areas. The two key characteristics of land management are ownership (public vs. private) and use ('reserved' for ecological integrity or 'working' for the production of commodities or a combination of the two).

Indicator

Land management in California (Type I)

Sub-issue 1.3: Threatened and endangered species

California has one of the most diverse assemblages of plants, animals, and natural communities in the United States. Human activities have threatened the viability of many populations of plants and animals, causing some to become threatened, endangered, or extinct. Both federal and state laws have been enacted to protect species at risk of extinction. Not only is the protection of these species important for the preservation of biodiversity, but the threatened status of a species indicates a decline in the status of the ecosystem as a whole.

Indicator

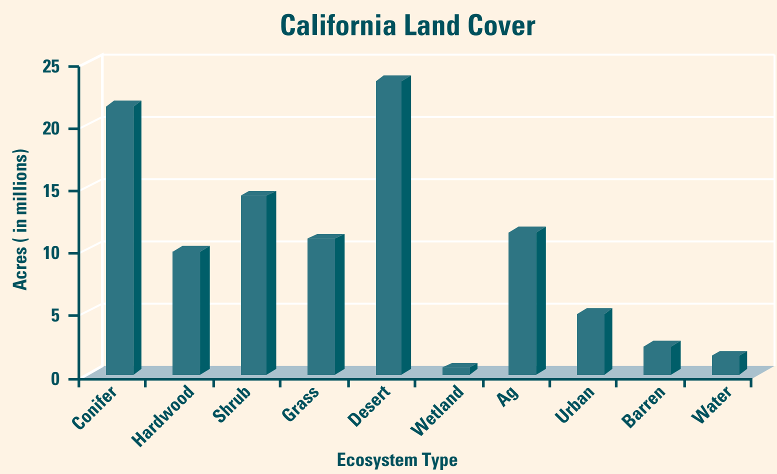
California threatened and endangered species (Type I)

Type I

Level 4
Goal 6

Land Cover Of Major Terrestrial Ecosystems In California

The extent of land cover in California as of 1997.



What is this indicator showing?

The indicator shows the current distribution and extent of natural and human-altered ecosystems in the state. Forests are subdivided into conifer and hardwood. Barren lands, those without any vegetation, are primarily those above the tree line. Water includes lakes, reservoirs, rivers, and streams. The graph below shows the total acreage in each broad category.

Why is this indicator important?

Land cover is a general measurement of the abundance of a particular ecosystem. Land cover measurements help classify the broadest categories of natural versus altered ecosystems. As the total acreages of land cover change over time, inferences can be made about changes to specific ecosystems or habitats that might be placed "at risk." Maps of changes in land cover can alert policy makers and planners to patterns in changes in land cover that are useful in decision making. The geographical presentation of the information is particularly useful for policy makers in minimizing fragmentation of wildlife habitat, a major threat to ecological health.

This indicator is essential to monitoring the extent and general condition of California's ecosystems. As information from the California Land Mapping and Monitoring Program evolves, repeatable information, spatially displayed for tracking changes in terrestrial ecosystems, will be available.

Land Cover of California

See full color map on page 255

What factors influence this indicator?

California contains approximately 100 million acres of land. The largest category is forested lands, which cover about 31 million acres. The desert is the next largest category, covering about 24 million acres, followed by shrub land, with 14 million acres, and grassland with about 11 million acres. Wetlands and water cover 2 million acres.

While this indicator portrays the broad categories of ecosystems, the underlying classification system that was aggregated to develop it provides very detailed descriptions of habitat extent and condition. These additional details are available on different layers of the Geographic Information System (GIS) maps developed and maintained by the Fire and Resource Assessment Program (FRAP) at the Department of Forestry and Fire Protection (CDF).

Technical Considerations:

Data Characteristics

No single vegetation mapping effort provides GIS data adequate to address broad resource issues throughout the state. In order to provide the most solid basis for statewide analyses, FRAP staff has used several digital map sources and merged them into a single GIS data layer.

A major component of the land cover data comes from the California Land Cover Mapping and Monitoring Program (CDF and U.S. Forest Service cooperative), which develops products for forest and range areas of California that cover approximately 65 percent of the state.

This program provides consistent, high quality data to manage, assess and protect California's diverse vegetative resources. Landsat Thematic Mapper (TM) satellite imagery is used to map vegetation over repeated five-year cycles. California Land Cover Mapping and Monitoring Program land cover products are developed to meet federal Geographic Data Committee standards and the needs of various state and local cooperators. Land cover map products include cover type, tree size and canopy closure attributes with a minimum map unit of 2.5 acres.

Many other data sources are used to create the land cover map. Some of the other sources include U. S. Geological Service (USGS) hydrography for water; U.S. Bureau of Census for urban areas; Department of Fish and Game wetlands data; and Department of Conservation Farmland Mapping Program for agricultural lands.

Strengths and Limitations of the Data

Combining disparate GIS layers is problematic due to differences in scale, accuracy, age, specificity and purpose of each individual data set. Merging data from multiple sources required addressing these differences in scale, resolution and consistency. In addition, each data set had to be cross-walked into a common classification system called the California Wildlife Habitat Relationships system (CWHR).

Spatial registration of these products to base maps between 1:60,000 and 1:100,000 scale limit the utility of the data for some applications. Users familiar with USGS 1:24,000 scale topographic maps and Digital Ortho Photo Quarter Quads (DOQQ) find these data coarse for planning projects "on the ground." Registration of obvious features such as lakes can vary and often have "blocky" rather than smooth edges. Features smaller than 2.5 acres are subsumed by surrounding vegetation types and small linear features such as roads and riparian corridors are not captured well.

References:

Fire and Resources Assessment Program (FRAP), California Department of Forestry, frap.cdf.ca.gov

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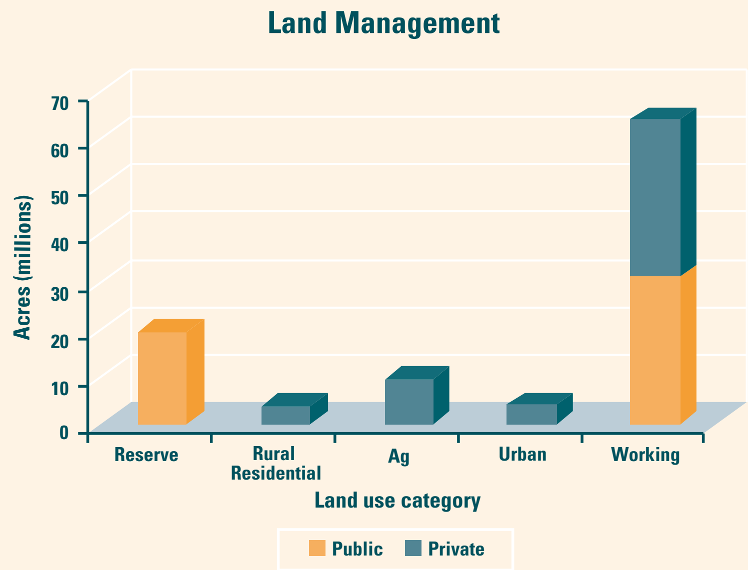
Type I

Level 4
Goal 6

Land Management In California

The ownership and management of land are shown by this indicator.



What is the indicator showing?

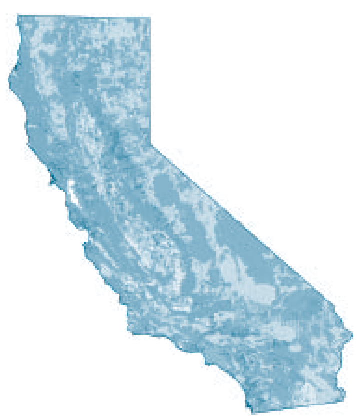
Nineteen percent of California lands are managed to maintain a high degree of ecological integrity (the Reserve category). Sixty-four percent of lands fall into the "working" category, which provides varying degrees of habitat value. The remaining lands are significantly transformed by human activities.

Why is this indicator important?

Identifying the major types of land management and uses is fundamental to understanding the impact that policy decisions have on current ecosystems. The **land cover** indicator defines natural vegetative types of land (e.g., desert, forest, grassland, aquatic, as well as agricultural and urban covers). This indicator, **land management**, defines the owner's primary objective for these lands, a key factor in determining the compatibility and flexibility for maintaining ecological integrity. For example, forests are typically managed as a working landscape for the production of timber when in private ownership, but can also be a reserve landscape when held by the state or federal government as a park. Changes in land management and use can have significant impacts on the integrity of the ecosystem. These changes include replacing natural biological communities with agricultural systems, altering chemical or hydrological cycles such as those caused by building dams, and changing the earth's surface by creating concrete-covered urban areas. Classifying land management is a fundamental step in understanding areas of undisturbed versus altered ecosystems, defining the components of ecosystems most at risk, and establishing a system for monitoring land use change.

The graph above shows that 19 percent of California lands fall into the Reserve category, indicating that they are managed to maintain a high degree of ecological integrity. About 64 percent of California lands are in the Working category, and these lands provide habitat of varying quality. The remaining lands are significantly transformed by human activities.

Land Management of California



See full color map on page 256

What factors influence the indicator?

This indicator reflects the present status of the combination of land management, ownership and major uses of land in the state. This indicator reflects the potential ecological impacts of land use decisions. Maintenance of overall ecological health is closely related to the use of the land. As land use decisions change, increases or decreases in ecological integrity result. In future years, trends will develop as additional data are collected. The map reflects acres of land in the following two classification schemes:

1. Ownership:
   - Public: those lands whose management goals are set through public procedure and by public agencies.
   - Private: those lands whose use is determined by the owner.
2. Land Management and Compatibility with Ecological Integrity:
   - Reserve: lands permanently managed for the maintenance of ecological integrity. Example: State parks, wildlife areas.
   - Working: lands managed for some degree of commodity output, but also for the maintenance of some degree of natural ecosystem integrity. Example: private timber production forests and ranches.
   - Agriculture: irrigated lands managed for the production of food or fiber with modest consideration given to ecological attributes in certain cases. Example: cotton, rice fields, or vineyards.
   - Rural Residential: lands where housing densities are more than one house per 20 acres but less than one house per acre. These lands are usually found within working or agriculture categories and reduce natural vegetation and habitat quality due to the presence of settlement.
   - Urban: lands having housing densities of one unit per acre or greater or commercial lands with very little ecological value.

The above categories are useful for understanding the key management goals of the land. However, within any category there are exceptions. For example, healthy creeks exist within some dense urban areas and dense developed areas exist within many parks and reserves.

Nearly 64 percent of the state's land is in the **working landscape** category. These lands are natural, managed ecosystems, such as forests, woodlands, and grasslands involving some level of commodity production or active recreational use but with a relatively high level ecological integrity. Nineteen percent of the land is publicly owned and reserved to promote ecological integrity. The rest of the landscape is fundamentally transformed by high-density urbanization (four percent), rural residential areas (four percent), or irrigated agriculture (ten percent). Reserve lands (19 percent) are far less prominent than lands that are highly managed (Working/Ag/Urban) and are unequally spread across the state. This distribution leads to protection of different ecosystems to different degrees and complicates management for ecological integrity.

Working landscapes such as forests and grasslands will potentially play a very important role in the future development of the state. First, they are important sources of natural areas and open spaces. They provide habitat for many species of animals and provide recreational opportunities for hundreds of thousands of people. On the other hand, it is likely that a significant portion of new urbanization will occur on these lands. Explicit land use planning is needed to maintain their ecological values.

Urban and various urban mixtures (rural, suburban, etc.) categories represent nearly eight percent of the state's land uses. These are the sites of the greatest population growth and present challenges to maintain some degree of ecological integrity.

Technical Considerations:

Strengths and Limitations of the Data

The data presented in this version are not highly maintained or updated. A new version, with updated mapping layers, is scheduled for release in 2002. Trend analysis between these versions is difficult due to changes in mapping techniques to improve "accuracy" of the information. Since the methods used to prepare this map are different than those that will be used in future versions, comparability will only be approximate.

References:

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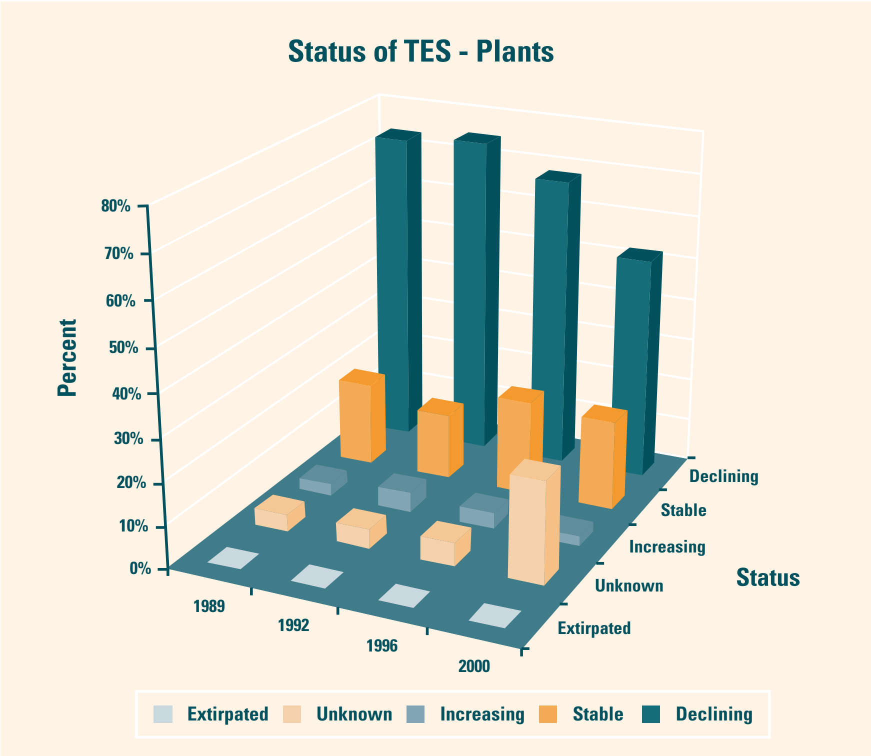
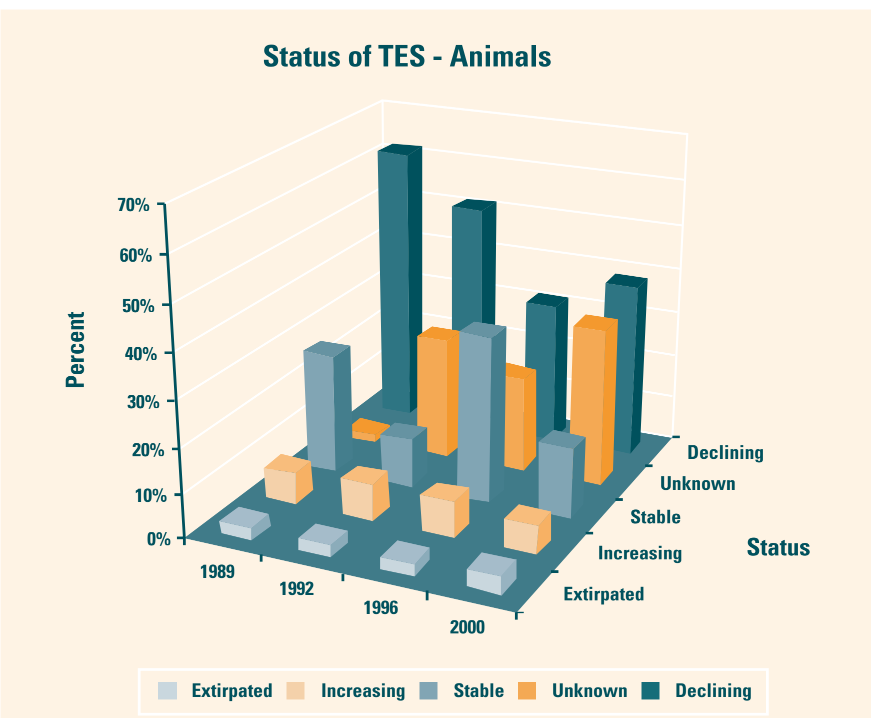
California Threatened and Endangered Species

Estimates of changes in the populations of plants and animals on the threatened and endangered species (TES) list.

Type I

Level 6
Goal 6





What is the indicator showing?

Over the past 12 years, plants on the California threatened and endangered species list with populations that are "declining" make up the largest category, while those whose populations are "increasing" represent the smallest category. Essentially no plants have been extirpated (species no longer found in California). The number of plants in the "unknown" category is increasing.

Between 1989-2000, trends for TES animals show that the percent of animals in the "unknown" category has increased. The population of about 5 percent of TES animals is "increasing". Since 1989, there appears to be a reduction in the number of animals in the "declining" category.

Why is the indicator important?

The status of threatened and endangered species (TES) is a useful indicator of biodiversity. Collectively, TES occur in a wide variety of habitats throughout the state. Changes in their abundance and distribution may indicate more substantial problems with many other species and habitats. These plants and animals are among the most sensitive to human impacts on our environment, such as habitat loss and degradation. They are listed as threatened or endangered because they "are in danger of or threatened with extinction because their habitats are threatened with destruction; adverse modification or severe curtailment, or because of overexploitation, disease, predation or other factors." These species are also among the most studied in the state. The California Department of Fish and Game regularly issues statewide status and trend information, based on professional judgment, on the status of species on the TES list.

What factors influence this indicator?

The fact that the "unknown status" category accounts for about 20 percent of TES plants and 35 percent of TES animals reflects substantial uncertainty. There is considerable need for more scientific data on the populations of many California threatened and endangered species to learn about their true status and condition. Insufficient resources do not allow for full assessment of population status of all listed plants and animals. Of additional concern is the fact that, with the exclusion of those TES that are extirpated, the "increasing" category for both animals and plants is the smallest category.

This indicator is influenced both by the nature of the data collection process and by factors that affect the long-term viability of individual species. These data represent the best professional judgment of biologists, but there is variability in both the assessment and reporting methods. Species viability in California is most strongly influenced by loss of habitat. This loss is due most often to urban expansion (National Wildlife Federation, 2001), but it also occurs when natural lands are converted for commercial uses or when water is diverted from natural channels. Habitat degradation is a secondary, though still very important factor. This loss in habitat quality may occur due to invasive species, increased human access during sensitive periods, creation of dispersal barriers, habitat fragmentation, and isolation of populations. For some species, other factors such as diseases, poisoning, roadkills, and pollution, are also important influences on population trends.

Technical Considerations:

Data Characteristics

The information in the graphs has been simplified for the sake of readability. The “stable to increasing” and “increasing” categories have been pooled to indicate the groups that are increasing; the “stable to declining” and “declining” categories have been pooled to indicate the groups that are in decline. Invertebrates were excluded as a species group due to the very limited number of species listed.

Strengths and Limitations of the Data

This indicator describes only those species that are listed under the California Endangered Species Act. Although this list overlaps somewhat with those species listed under the federal Endangered Species Act, it does not include approximately 112 federally listed species. It also does not include some 1,400 other species that are considered biologically rare or sensitive in the state. The California Department of Fish and Game issues regular reports on the status and trends of state-listed species, although due to funding limitations these reports rely heavily on professional judgments. These judgments will vary from year to year and from species to species, depending on current staff expertise, and degree of coordination with other agencies and organizations that are familiar with individual species.

References:

California Department of Fish and Game. 2001. *The Status of Rare, Threatened, and Endangered Animals and Plants of California Annual Report of 2000*. State of California, Resources Agency.

National Wildlife Federation. 2001. *Paving Paradise: Sprawl’s Impact on Wildlife and Wild Places in California*. Posted at: www.nwf.org/smartgrowth/pavingparadise.html.

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Indicators

Status of Central Valley Chinook Salmon Populations (Type I)

California Least Tern Populations (Type I)

Stream Bioassessment – Invertebrate Populations (Type II)

Persistent Organic Pollutants in Harbor Seals (Type III)

Endocrine-Disrupting Chemicals in Aquatic Ecosystems (Type III)

Issue 2: Health of Aquatic and Coastal Ecosystems

Sub-issue 2.1: Aquatic life protection and biodiversity

The animals and plants that live in coastal/marine and freshwater/inland waters are valued resources and their diversity and abundance are key factors that reflect the health of these environments. These natural resources are threatened by loss of habitat and competition with introduced species, as well as degradation in water quality and depletion of natural resources beyond the system's capacity to recover.

Indicators selected to represent this issue are identified in the box below. Chinook salmon and least tern were selected as sentinel species for instream and coastal fish and birds since reliable data are available. To assess of the quality of the aquatic habitat, the Stream Bioassessment, a measure of the abundance and diversity of stream invertebrates, was chosen as an indicator. Since invertebrates such as fly larvae are near the base of the aquatic food chain, the status of these organisms will impact many other aquatic species. Additionally, they are among the most sensitive to contaminants. Two additional issues of importance to the biodiversity of the aquatic ecosystems are the bioaccumulation of persistent organic pollutants (i.e., dioxins and polychlorinated biphenyls) and the presence of endocrine disrupting chemicals. Both can interfere with reproduction and thus have significant effects on populations of aquatic organisms.

Indicator

Clarity of Lake Tahoe (Type I)

Sub-issue 2.2: Habitat and water quality protection

The maintenance of aquatic resources is dependent upon preservation of physical habitat as well as suitable water quality and quantity. California has over 10,000 lakes, reservoirs, and ponds and over 64,000 miles of perennial rivers and streams. Its coast is nearly 1000 miles long. California contains valuable wetlands, both along the coast and inland, the majority of which have been lost or substantially changed. Changes in physical parameters such as substrate type, temperature, salinity, and dissolved oxygen can have substantial effects on the biological resources in aquatic ecosystems as well. Excess nutrients, such as nitrogen and phosphorus, can lead to eutrophication, a condition in which algae depletes light and oxygen in the system. Contaminants such as heavy metals and polycyclic aromatic compounds can collect in the sediment, presenting a risk to many aquatic organisms. Key abiotic resources, such as water quality and quantity, are essential to maintaining the health of aquatic ecosystems. Urbanization and infrastructure development, industry, commercial shipping and fishing, and recreational activities are additional factors that have the potential to negatively impact aquatic habitats.

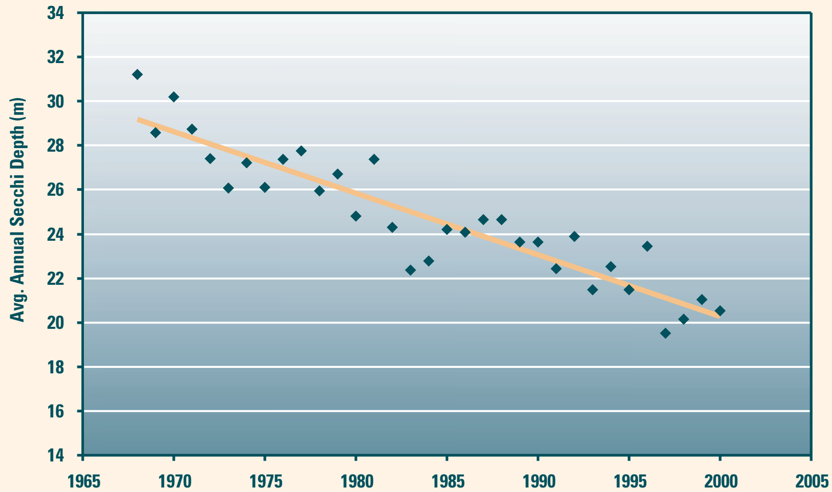
The indicator to represent the status of aquatic habitat is the Clarity of Lake Tahoe, a measure of the extent of nutrient and sediment pollution, leading to eutrophication. Eutrophication of lakes is often a consequence of human activity in or around aquatic habitats. In future years, additional lake monitoring data from throughout the state, as well as other indicators of aquatic habitat, will be added to the report.

Clarity of Lake Tahoe

Transparency of lake water is an indicator of ecological health.

Type I

Level 6
Goal 2, 4, 6



What is the indicator showing?

The clarity of Lake Tahoe's water has decreased since 1968. These changes are associated with eutrophication, a process where nutrient levels rise and cause plant and algae growth to increase. In addition, suspended sediments have contributed significantly to decreased clarity.

Why is this indicator important?

Lake Tahoe, a pristine, crystal-clear high altitude lake, is considered one of the 'jewels' of the Sierra. As such, Californians place a high value on the ecological condition of this lake. While this indicator only reflects the ecological condition of the Lake Tahoe watershed area, this type of assessment can be used to determine the condition of other developed watershed areas containing lakes. The graph above shows decreases in lake water clarity measured by the depth that a round disk can be seen when lowered into the lake. It is indicative of eutrophication, a natural aging process in lakes that involves increased amounts of nutrients and algae in the water, with one of the most noticeable results being reduced water clarity. Human activities, especially those that cause increases in the concentration of nutrients such as phosphorus, can cause higher than normal rates of eutrophication, as observed in Lake Tahoe. Increases in lake algae can change the appearance and even odor of a lake, and can cause periodic decreases in water oxygen levels. Oxygen depletion can harm many organisms and fundamentally change the ecology or the types of life that can survive in the water body. For example, the suitability of the lake to support cold water fish such as trout, sucker, and Kokanee salmon may decrease in advanced stages of eutrophication. More information about changes at Lake Tahoe can be found on the website of the University of California at Davis Tahoe Research Group (see references).

What factors influence this indicator?

Data collected at Lake Tahoe since the late 1960s indicate that water clarity has decreased. Water in the lake has been losing transparency at an average of about one foot per year, a decrease of 34 percent since 1968. During this same period, biological changes such as increases in algae growth along the edges of the lake have been observed. These changes have been associated with inputs of nutrients from the atmosphere and the watershed as well as from suspended clay and silt particles brought in through streams (Tahoe Research Group, 2000). Watershed land-use practices and atmospheric inputs are primary factors that influence the clarity and trophic state of Lake Tahoe. Typical causes of accelerated eutrophication in lakes include changes in watershed practices that allow for increased erosion and nutrient release and the input of nutrient-rich urban or agricultural runoff water.

Technical Considerations:

Data Characteristics

This indicator represents eutrophication-related problems in lakes. It is an integrative indicator since the algal component of clarity loss infers changes in biologically meaningful characteristics such as algae biomass, invertebrate and fish assemblages, nutrient levels, and oxygen concentration profiles. A long-term data set on water clarity readings at Lake Tahoe has been carefully maintained and made available by UC Davis researchers (Tahoe Research Group, 2001; Horne and Goldman, 1994). In addition to being simple and relatively easy to understand, this type of indicator is being used in other states around the country through a national volunteer-based water clarity monitoring effort, offering the opportunity to compare our findings with those of other states (The Great North American Secchi Dip-In Website, 2001).

Clarity measurements were made using a Secchi disk that was lowered into the lake water. A Secchi disk is a flat, 8 or 10 inch black and white disk that, when lowered into the water, provides a measure of optical clarity measured at the depth where the disk can no longer be seen. Annual averages of these measurements were used for Lake Tahoe since clarity readings on this lake are measured every 12 days.

Strengths and Limitations of the Data

Clarity measurements with Secchi disks are simple and relatively robust indicators of lake health. Because of Lake Tahoe's large size and relatively small watershed, as well as its high altitude, pristine condition, and urbanized setting, it is fairly unique among California lakes. Lake Tahoe is monitored frequently; however, there are many lakes in the state for which no such readings are taken. Some regions and programs monitor extensively, such as the Department of Water Resources' Northern District, while others monitor very little. Fragmented data sets, with gaps in both spatial and temporal coverage of California lakes, have been obtained for less than one percent of California lakes, reservoirs, and ponds. To assess the health of California lakes, monitoring efforts may be warranted for other lakes, such as Lake Elsinore, Salton Sea, Mono Lake, and Clear Lake, on a regular basis. The Secchi disk readings may not always be the most appropriate indicator of lake health for all lakes, and in such cases more appropriate measurements should be made so that responsible agencies and the public have information about the health of a key natural resource.

References:

Horne, A.J., C.R. Goldman. 1994. *Limnology*. McGraw-Hill, Inc., New York. pp.507-508

The Great Secchi Disk Dip-In Website, dipin.kent.edu/

U.C. Davis-Tahoe Research Group. 2000. *Annual Progress Report 2000, Water Quality, Air Quality & Forest Health*. trg.ucdavis.edu.

U.C. Davis-Tahoe Research Group. 2001. Lake Tahoe Index Station Data Supplied by U.C. Davis-Tahoe Research Group.

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Type I

Level 6
Goal 6

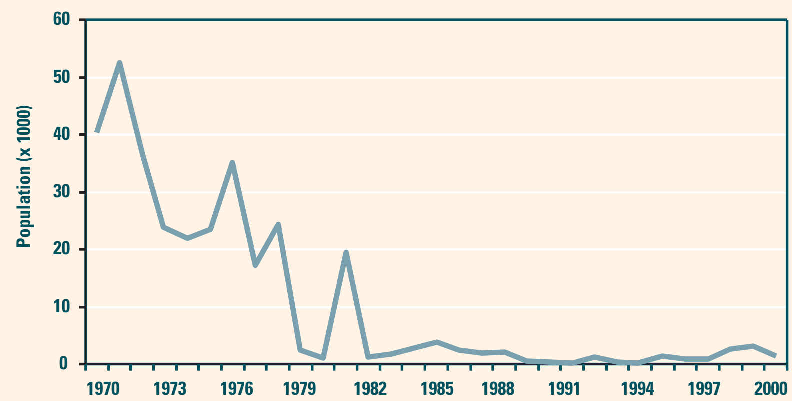
Status of Central Valley Chinook Salmon Populations

The status of Central Valley chinook salmon populations is a general indicator of the health of river systems in the Central Valley.

What is the indicator showing?

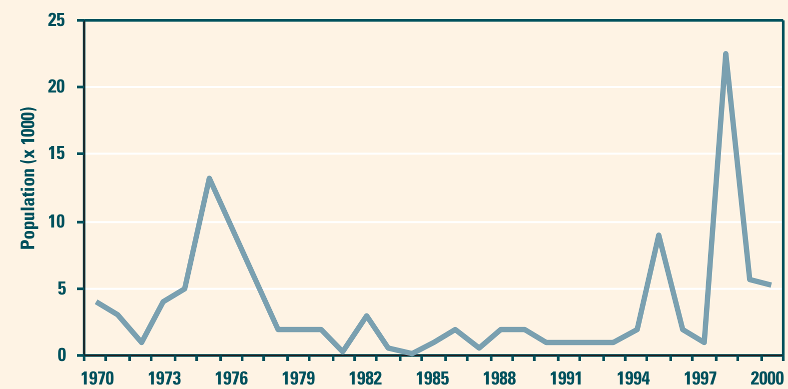
The endangered winter-run chinook salmon population has shown a significant decline over the past 30 years. In recent years, population levels have increased, but remain well below levels defined for recovery.

Sacramento River Winter-Run Chinook



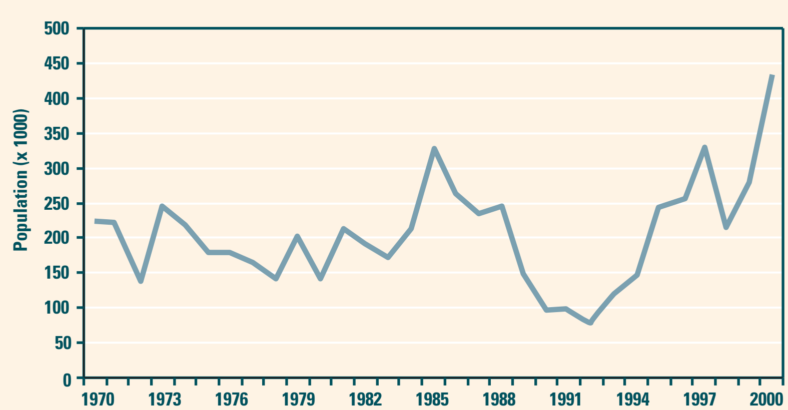
Spring-run salmon populations in Mill, Deer, and Butte Creeks, tributaries of the Sacramento River in the northern Sacramento Valley, have shown some recovery in recent years. These three creeks support the only remaining significant non-hybridized populations of the threatened Central Valley spring-run chinook.

Spring-Run Chinook in Sacramento River Tributaries



Spawning returns of fall-run chinook salmon in the Central Valley have fluctuated over the past 30 years, showing some increase in recent years. Fall-run chinook salmon returns are significantly influenced by hatchery production and ocean harvest regulations.

Central Valley Fall-Run Chinook



Why is this indicator important?

Four chinook salmon runs are recognized in the Central Valley, differentiated by the timing of the adult spawning migration (fall, late fall, winter, and spring-run chinook salmon). Chinook salmon have been historically valued and have become part of the cultural and natural heritage of northern California. Commercial and recreational fishing for salmon has contributed significantly to the economy. The estimated California economic impact for 2000 was approximately $40 million dollars. Historically, this contribution has been much greater (PFMC, 2000).

Many of the salmon runs in the Central Valley are on the federal or state endangered species list: Sacramento River winter-run chinook salmon is state and federally-listed as endangered, Central Valley spring-run chinook salmon is state and federally-listed as threatened, and Central Valley fall and late fall-run chinook salmon are federally designated as a candidate species. Historically, these runs were abundant in the waters of the Sacramento and San Joaquin Rivers. Narratives from the late 1880s describe these rivers as "teeming with salmon" (Yoshiyama et al., 1998). Based on data from early commercial catch records, scientists at University of California, Davis conservatively estimate that chinook salmon stocks reached between one to two million spawners annually. Today, the winter and spring runs are a fraction of their historic levels (Yoshiyama et al., 2000). Significant regional efforts, including the CALFED Bay-Delta Program and Central Valley Project Improvement Act (CVPIA), have devoted considerable resources to the recovery of these runs.

What factors influence this indicator?

Because the winter and spring runs typically spawn farther upstream than the fall-run salmon, their populations have been most significantly impacted by dam building in the state. Blockage of access to spawning and rearing areas due to dam construction has had the greatest impact on these runs, significantly reducing the availability of habitat from historic levels. Other factors contributing to the decline include ocean harvest, changes in the frequency, amount and timing of instream flows, water temperature changes, delay of passage at artificial barriers, contaminant discharges, loss of riparian habitat, loss of spawning gravel, and accidental trapping of young fish in water diversions. In many cases, these stressors pre-date 1970, but their effects continue to the present.

In contrast to the winter run, the population of spring-run chinook salmon in Mill, Deer, and Butte Creeks have fluctuated in the past 30 years, showing some recovery in recent years. This recovery has been associated with a number of factors, including the removal of diversion dams, instream habitat and flow improvements, and improved watershed management.

In general, fall-run chinook populations in the Central Valley have been more stable over the past 30 years. Fall-run salmon have fared better in part because they spawn primarily in the lower reaches of the rivers, those below 1000 feet elevation, in reaches that have not been obstructed by dams. The life history of fall-run chinook is more compatible, in general, with current water management practices in the Central Valley as well. However, the number of fish that return to freshwater to spawn naturally, also referred to as escapements, in the Sacramento River basin are influenced by hatchery production (PFMC, 2001); hence the size of the Sacramento basin runs may be a poor indicator of ecological health. The abundance of natural fall-run chinook in the San Joaquin River basin, less influenced by hatchery production, continues to be low following several above-average water years.

Significant concern exists regarding the genetic effects of hatchery rearing on wild salmon populations. Some studies suggest that hatchery-raised fish are less successful than wild fish in reproducing under natural conditions (Levin and Schiewe, 2001). Long-term hatchery production may adversely affect the fitness of wild populations in a variety of ways. The National Academy of Sciences recently released an analysis of the genetics of Atlantic Salmon, another salmonid in a related genus, and found distinct differences between hatchery and wild fish, those spawning naturally for at least two generations (National Academy of Sciences, 2002). This report may provide some insight into genetic differences between hatchery and wild chinook salmon.

Due to concerns over habitat degradation, threats to genetic integrity due to hatchery production, and relatively high ocean and inland harvest rates, Central Valley fall-run chinook have been designated, along with the late fall-run, as a candidate species under the federal Endangered Species Act.

Technical Considerations:

Data Characteristics

Spawning populations of chinook salmon are estimated each year by carcass surveys, direct counts at dams, redd (spawning nest) counts, and snorkel surveys. Carcass survey estimates are based on a mark-recapture method. Population sizes are statistically estimated from the sequential sampling of tagged salmon carcasses.

Strengths and Limitations of the Data

The population estimation process is subject to error and provides reasonable estimates rather than exact numbers. Estimates of natural spawners include both hatchery-reared fish and fish spawned in the wild. At present, the contribution of hatchery-reared fish to the natural spawning escapement is not known with any degree of accuracy.

In addition, spawning escapement surveys cannot assess the effects of different stressors on the populations. The number of fish that return to freshwater to spawn is affected by numerous environmental factors and by rates of harvest in both ocean and inland areas.

There is a need for improved monitoring of chinook salmon populations in the Central Valley, including the ability to differentiate between hatchery and wild fish. Fishery management agencies such as National Marine Fisheries Service, California Department of Fish and Game, and U.S. Fish and Wildlife Service are working toward improved monitoring programs, in part through funding provided by programs pursuant to the Central Valley Project Improvement Act (CVPIA) and the CALFED Bay-Delta Program.

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Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 2000. *Chinook salmon in the California Central Valley: An assessment*. Fisheries. 25: 6–20.

CALFED Bay-Delta Program, www.calfed.ca.gov.

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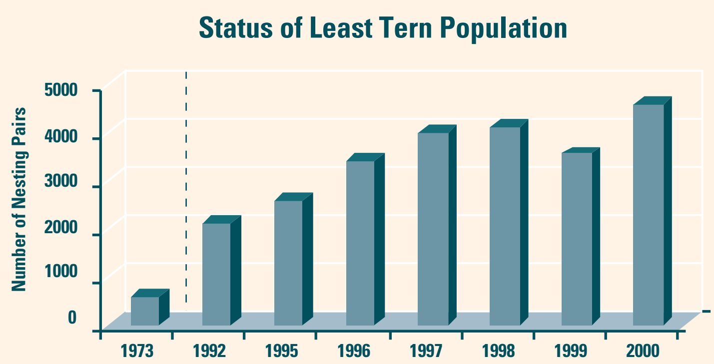
Type I

Level 6
Goal 6

California Least Tern Populations

Populations of this bird, which is on the federal and state lists of endangered species, have partially recovered.



What is the indicator showing?

The least tern population has improved since 1970, but in the late 1990s, the rate of increase in the population slowed. Since much of its nesting habitat is disturbed by humans, these birds need to be monitored closely in the future.

Why is this indicator important?

The California least tern, a seabird on both the federal and state endangered species list, nests in colonies on sandy beaches and other flat, open areas along the coast. Nesting habitat along the coast has been degraded by habitat modification and human disturbance. Rising least tern populations signify the success of intensive management efforts, including monitoring of nesting colonies, protecting nesting sites by reducing human access, managing vegetation, and controlling predators.

What factors influence this indicator?

The population of least tern has been increasing, with a reproductive success rate of 0.7 fledglings per adult pair. The number of active breeding sites remains steady at between 34 to 39 sites during the 1990s. Most of the population increase is accounted for by the robust growth in 9 or 10 large colonies, while most other sites have populations that are either decreasing, not significantly increasing, or generally do not have good breeding success.

In the early 1970s, when California least terns were listed as endangered by the federal government and California, their population in California was estimated at 600 breeding pairs. Active management of the tern began in the 1970s and intensified in the 1980s. By 2000, the population had increased to about 4600 pairs, nearly an eightfold increase.

California least terns are migratory birds that winter in Latin America and nest along the Pacific coast from southern Baja California to San Francisco Bay. They nest in colonies on bare or sparsely vegetated flat areas on the coast. Nesting sites are now on isolated or specially protected sand beaches or on natural or artificial open areas in remnant coastal wetlands, in places where small fish are abundant. Development and recreational use of California's coast have largely eliminated the natural nesting habitats of the terns (DFG, 2000). Human activities and predators associated with humans (e.g., domestic cats, non-native red foxes, crows, and ravens) continue to place nesting colonies at risk.

Interestingly, the Alameda Naval Air Station is one of the largest and most successful breeding colonies in the state, and the only substantial colony in northern California. The terns have nested on the runways of the Naval Air Station for years, and the Navy managed the colony. As part of the federal government's disposal of the Naval Air Station, a 500-acre parcel including the runways was transferred to the U.S. Fish and Wildlife Service to be included in the San Francisco Bay National Wildlife Refuge. Larger breeding populations regularly nest at Camp Pendleton, Mission Bay, Huntington State Beach, and Venice Beach.

Technical Considerations:

Data Characteristics

California least terns compete with humans for one of the most valuable and scarce resources in the state — undeveloped coastal lands. The fact that the terns survive on remnant nesting sites amidst a highly developed landscape demonstrates that intensive wildlife management efforts can succeed.

Strengths and Limitations of the Data

Annual surveys of tern colonies are conducted by cooperating agencies including military facilities, the U.S. Fish and Wildlife Service, and the California Department of Fish and Game, with valuable help from private groups and other volunteers. However, ongoing surveys are dependent on adequate funding.

Reference:

DFG, 2000. *The Status of Rare, Threatened, and Endangered Animals and Plants of California, Annual Report.* California Department of Fish and Game.

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Type II

Stream Bioassessment – Invertebrate Populations

Why is this indicator important?

Biological assessments or bioassessments are evaluations of the condition of water bodies using surveys and other direct measurements of resident biological organisms, i.e., invertebrates, fish, and plants. The health of aquatic ecosystems has traditionally been assessed with indirect measures emphasizing chemical tests. Bioassessment, on the other hand, is a direct measure of the condition of aquatic organisms so that any potential adverse effects of multiple aspects of poor water quality or inadequate habitat can be evaluated. U.S. EPA has been working with California to develop a cost-effective and reliable measure of the physical and biological integrity of the state's water bodies. The goal of this project, known as the Western Pilot Environmental Monitoring and Assessment Program (E-MAP), is to conduct physical and biological assessments and develop Indicators of Biological Integrity (IBI) for a variety of aquatic organisms. The Department of Fish and Game has recently completed Year one of a four-year monitoring effort to conduct bioassessment in streams of California. Because streams were randomly selected throughout the state, the results of this bioassessment effort should accurately reflect the condition of streams throughout California. U.S. EPA's intent is to have a first set of data points out for review by the year 2004 and then to turn the project over to the state for modification and long-term implementation.

Invertebrates living in the sediment of streams, also known as benthic macroinvertebrates, are the focus of California's effort. They are being collected, counted, and classified according to species. Several biological metrics are used to calculate the "health" of the macroinvertebrate population, including taxa richness, community composition, tolerance measures, and feeding guilds. These values are then used to calculate the benthic macroinvertebrate IBI. High IBI values indicate a healthy population of macroinvertebrates.

What factors influence this indicator?

The IBI will tell us a great deal about the overall health of aquatic ecosystems. When human activities have detrimental effects on streams, the IBI value declines. Bioassessment measures key components of the aquatic ecosystem - biological community diversity, productivity, and stability. The degradation of the physical habitat, which can include alteration of substrate type, tree cover, and appropriate stream or river bottom, is a key factor that is important to the health of aquatic organisms. Poor water quality associated with factors such as high levels of suspended particles, changes in water temperature or water quantity, pesticide runoff, or effluent from industrial activities, can also adversely affect aquatic ecosystems. In many cases, mortality or impairment of reproduction occurs at contaminant levels much lower than those that affect fish. Since macroinvertebrates serve as food for fish, and in turn, fish serve as food for birds and mammals, the status of these organisms is important for maintenance of the health of the entire aquatic ecosystem.

Reference:
California Department of Fish and Game, Aquatic Bioassessment Workgroup website:
www.dfg.ca.gov/cabw/cabwhome.html

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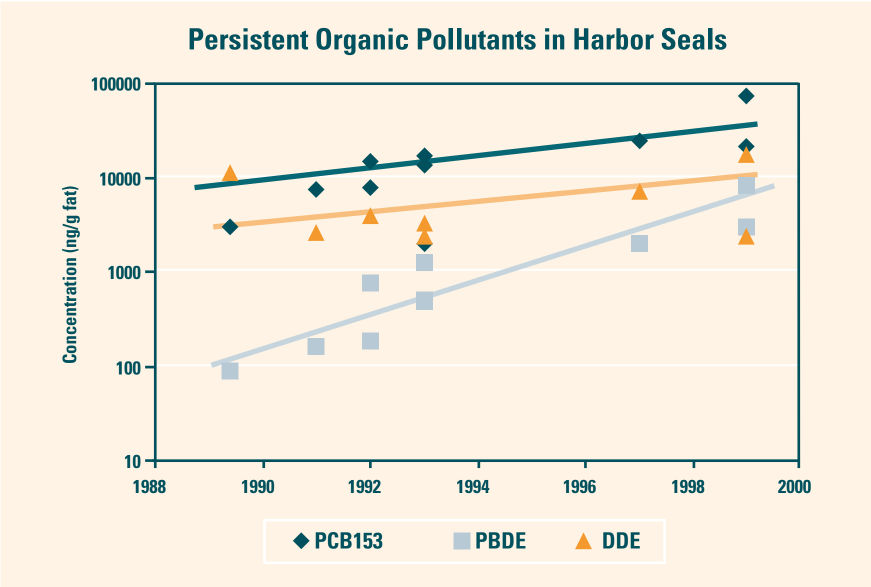
Persistent Organic Pollutants in Harbor Seals

Type III



What is the indicator showing?

This pilot study shows that certain POPs are accumulating in harbor seal blubber. There was an exponential increase in PBDEs, a small increase in PCBs and no change in organochlorine pesticides (DDE shown) over the last decade. Data for this graph came from analysis of fat tissue of nine harbor seals killed in boating or other accidents.

Why is this information important?

Persistent organic pollutants (POPs) are fat loving or lipophilic contaminants that include polychlorinated biphenyls (PCBs), polybrominated diphenylethers (PBDEs) (reviewed by Hooper & McDonald, 2000), and DDT. PCBs, used in transformers as hydraulic fluid and as a lubricant, and DDT, a pesticide, are both now banned for most uses in the U.S. Whereas PCB can be measured directly, DDT is metabolized to DDE, which is the form that is most often measured in tissues. PBDEs are a family of chemicals used as flame retardants in plastics, foams, and textiles. POPs have been associated with reproductive and developmental toxicity, cancer, immune system suppression, and other types of dysfunction. They are long-lived chemicals, with half-lives averaging between two and 10 years in animals and up to 75 years in the environment. Half-life refers to the time it takes for the concentration of a chemical to decrease by 50 percent. As a result, they readily accumulate in the fatty tissues of both animals and humans. Because of their toxicity and environmental persistence, they have the potential to cause significant harm to aquatic animals.

Most organic contaminants, including POPs, accumulate in the sediments of coastal and ocean waters. Seals, as predators within the coastal food web, consume smaller aquatic organisms, especially those that live in sediment. These contaminants bioaccumulate in seals, making their levels in tissue a good indicator for POPs in the coastal/marine ecosystem. This indicator alerts us to the presence of POPs, but does not provide information about its effect on the health of seals or the aquatic ecosystem as a whole.

What factors influence this indicator?

The dramatic increase in the levels of PBDEs over the ten-year monitoring period may be associated with the documented global increase in production and use of PBDEs; however, no specific data exist for the Bay Area. These chemicals increased from 55 nanograms/gram fat tissue to over 3000 ng/gram fat over the 12-year monitoring period. The pattern observed in San Francisco Bay varies from what has been observed in other places around the world. In most cases, PCBs and DDT metabolites (DDE and others) are no longer increasing but are nonetheless 10 - 500 fold higher than PBDEs (Hooper & McDonald, 2000). PBDEs are used widely today and may cause many of the same harmful effects as the other POPs (Darnerud et al., 2001). In other parts of the world, control measures have resulted in curbing PBDE body burdens in marine mammals, yet no comparable controls are presently in place in the U.S.

Although banned, the increase in PCB levels in seal blubber probably reflects their long-lived nature; they are known to persist in and be released from the sediment for 75 years or more. Similarly, one might expect DDE levels to decline in seal blubber since it has also been banned. The fact that the DDE levels have remained stable over the past ten years indicates that, like PCBs, the sediment still retains small quantities that are passed through the food chain to seals.

Technical Considerations:

Data are presented on a logarithmic scale. The log scale was used to allow for the presentation of concentration data in a smaller sized graph. Beach-cast harbor seals are tracked by the University of California at Berkeley Museum of Vertebrate Zoology and the Marine Mammal Center. Field personnel examine the seals and obtain specimens for analysis, conducted by the Department of Toxic Substances Control's (DTSC) Hazardous Materials Laboratory. Biometric and chemical data are compiled in a database maintained by DTSC.

These data are powerful at examining trends and the study design allows for additional chemicals of emerging concern to be added, if needed. The limitation is the limited number of individual seals tested and the lack of stable funding and commitment for the field and laboratory work. To date, sample collection has been limited to San Francisco Bay seals, but the methodology is applicable to other coastal regions. In the future, analysis of seals at various points along the California coast would provide a better indication of ambient conditions all along the coast.

References:

Darnerud., P.O., G.S. Eriksen, T. Jóhannesson, P.B. Larsen, and M. Viluksela, 2001. *Polybrominated diphenyl ethers: occurrence, dietary exposure, and toxicology*. Env. Health Persp., 109 (Suppl 1): 49-68.

Hooper, K., and T.A. McDonald, 2000. *The PBDEs: An emerging environmental challenge and another reason for breast-milk monitoring programs*. Env. Health Perspect. 108: 387-392.

She, J., M.X. Petreas, J. Winkler, P. Visita, M. McKinney, and D. Kopec, 2001. *Polybrominated diphenyl ethers (PBDEs) In the San Francisco Bay Area: Measurements in harbor seal blubber and human breast adipose tissue*. Chemosphere, In press.

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Endocrine-Disrupting Chemicals in Aquatic Ecosystems

Type III

Endocrine disruptors are chemicals that interfere with the action of hormones, natural chemicals that control many functions within an organism. One major class of endocrine disrupting chemicals (EDC) are xenoestrogens, those that mimic the action of estrogen, a key female sex hormone. Xenoestrogens can inhibit the normal development of male sexual structures in aquatic animals and stimulate the growth of female sexual organs and tissues. Effluent from wastewater treatment plants is known to contain chemicals that are xenoestrogens, specifically, ethinyl estradiol, a breakdown product of the estrogen in birth control pills. Xenoestrogens, in the concentrations present in effluent, might cause sexual changes in fish. A recent report on salmon in the Columbia River found that 85 percent of the females were genetically male, suggesting sex alteration had occurred that could impair reproduction, although water chemistry analysis was not performed (Nagler et al., 2001). Similar results have been reported for salmon in a number of California rivers as well (Williamson et al., 2001). It remains to be seen if EDCs or other environmental disturbances are responsible for this phenomenon.

At present, no regular monitoring is conducted in California for the presence of EDC in wastewater treatment plant effluent. There is a need for biological and/or chemical monitoring in the rivers of the state, especially those that are home to threatened or endangered species. Future indicators should address this important issue.

References:

Nagler, J.J., J. Bouma, G.H. Thorgaard, and D.D. Dauble. 2001. *High incidence of a male-specific genetic marker in phenotypic female Chinook salmon from the Columbia River*. Env. Health Perspect. 109: 67-69.

Williamson, K.S. and B. May, 2001. *Sex-reversal of male chinook salmon (Oncorhynchus tshawytscha) in the Central Valley*. Abstracts, Coastwide Salmonid Genetics Meeting, Bodega Bay, CA.

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Issue 3: Desert Ecosystem Health

The Mojave and Colorado deserts of southern California occupy an area of just under 25 million acres, about 25 percent of the state's land. Deserts contain unique plant and animal communities that have evolved to survive in extreme conditions. Strong sunlight, high temperatures, low soil fertility, and little rainfall allow the survival of only those species that can withstand and succeed under such conditions. Compared with more temperate ecosystems, the desert has relatively low diversity of plants and animals. Soils are fragile, and activities that disturb soil crusts and remove vegetation quickly bring about wind and water erosion. Because of the extreme conditions in the desert and unlike other ecosystems within the state, recovery from human impact takes decades, even centuries.

Indicator

Status of the desert tortoise population (Type I)

Sub-issue 3.1: Alteration in biological communities

The degradation of habitat quality has led to the loss of native plants and plant communities and has increased the opportunities for non-native and invasive species. Nitrogen oxides (NO_x) blown in from the Los Angeles and Riverside air basins as well as off-highway and military vehicles and automobiles have increased the nitrogen content of the soil. Since nitrogen is one key limiting factor for plants in the desert, the higher level of soil nitrogen has allowed many exotic annuals and grasses to become established in the deserts, competing with native annuals there. The increased biomass then leads to an increased frequency of fires and changes in the biological communities of the desert. It has been suggested that changes in the plant communities might be one factor related to the decline in the population of desert tortoise, a threatened and endangered species.

Indicator

Impacts of off-highway vehicles on the desert (Type II)

Sub-Issue 3.2: Habitat degradation

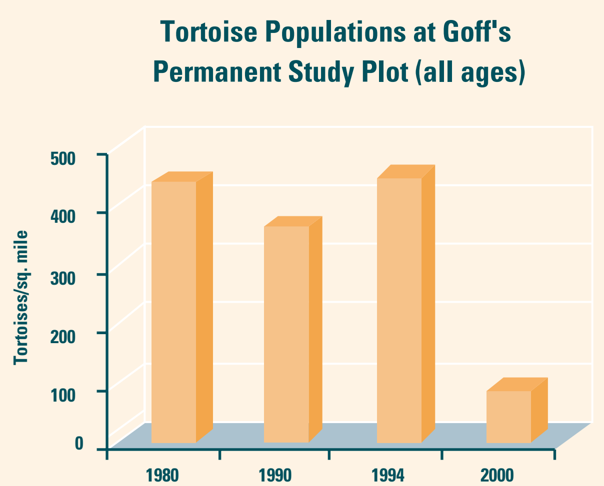
Military activities, off-road vehicles, and grazing compress the soil and destroy vegetation that stabilizes the surface of the soil and sand and provides food and habitat for animals. Compaction increases erosion and reduces the infiltration of water into soils. Fewer plants succeed and reproduce in compacted or disturbed soils. Recovery in desert ecosystems occurs much more slowly than in locations with more precipitation, i.e., decades and centuries in contrast to months and years. The disruption caused by off-highway vehicles is one of the important anthropogenic stressors on desert ecosystems.

Status of the Desert Tortoise Population

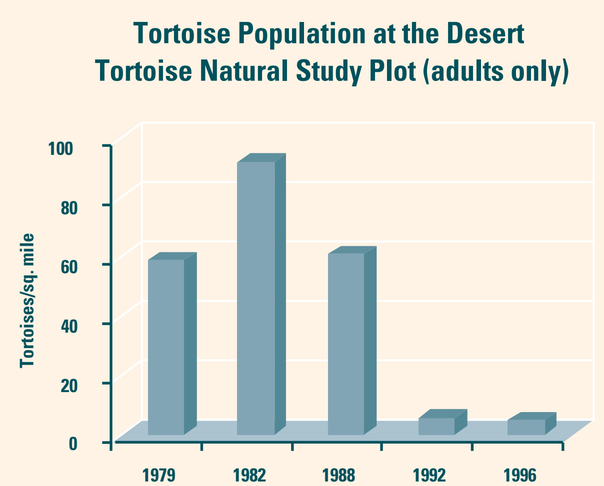
Desert tortoises are sensitive to environmental stressors.

Type I

Level 6
Goal 6



Source: Berry, 2000



Source: Brown et al., 1999

What is the indicator showing?

Desert tortoise populations, based on data from two study plots, have declined substantially in the past decade due to a wide variety of causes.

Why is this indicator important?

The U.S. government treats the desert tortoise as an indicator to measure the health and well being of the desert ecosystem. The tortoise functions well as an indicator because it is long-lived, takes 12-20 years to reach reproductive maturity, and is sensitive to changes in the environment (Berry & Medica, 1995).

Desert tortoise populations have declined dramatically because of human and disease-induced mortality, as well as destruction, degradation, and fragmentation of their habitat. As of 2002, there are no stable or increasing populations of tortoise in areas designated as "critical habitat" by the U.S. Fish and Wildlife Service. The health of the tortoise population reflects on the overall health of the desert ecosystem.

What factors influence this indicator?

The U.S. Fish and Wildlife Service (USFWS) listed the desert tortoise as a threatened species in 1990. The tortoise's range includes parts of the Mojave, Colorado, and Sonora Deserts. In California, 27 permanent desert tortoise study plots were established between 1971 and 1980. During this time, high mortality rates were documented in some parts of the desert from illegal collecting, road kills on highways and from off-road vehicle use, raven predation, and shooting. Habitat deteriorated or was lost due to urban and agricultural development, roads, freeways, pipeline and transmission line corridors, mining, livestock grazing, and fires. During the 1990s, diseases and invasions of alien plants have been added to the list of problems (Brown et al., 1999).

Between 1979-1980 and 1989-1990, tortoise populations in the western and southern Mojave Desert and the eastern Colorado Desert declined primarily due to human activities. Declines on some study plots ranged from 30 to 90 percent. At the time of listing, the population at the Goff's study plot in Fenner Valley, Eastern Mojave, was considered "the Gold Standard" for a stable population. Tortoise populations on two other plots in the Ward and Chemehuevi Valleys in the Colorado Desert, located in southeast California, were increasing between 1979 and 1990 (Berry, 1999). Populations plummeted at the Goff's and Chemehuevi Valley plots in the late 1990s. (Berry, 1999, 2000) Numbers of adult tortoises found on the plots declined 84 percent at Chemehuevi Valley between 1992 and 1999, while the number of tortoises found on Goff's plot in 2000 declined roughly 90 percent from earlier surveys.

Most recently, populations of tortoises appear to be dying of upper respiratory tract disease, shell disease, and elevated levels of several elements such as arsenic. Additional research is underway to understand the population declines. Shell diseases appear to be associated with toxic elements, such as arsenic and/or nutritional deficiencies. Identification of the most important factors affecting the tortoise population is key to its recovery.

Technical Considerations:

Data Characteristics

A Recovery Plan for the Mojave Desert Tortoise population was prepared in 1994. As part of the Recovery Plan, USFWS is coordinating the efforts of several federal and state agencies to estimate current tortoise population densities. This information will be developed over the next 3-5 years by sampling selected transects of the desert. After the baseline population density is established, the same transects will be monitored every three to five years to determine changes in the tortoise population densities. This is the first year (2002) of line distance sampling throughout the desert tortoise critical habitat within the Mojave Desert. Data has also been collected by the U.S. Geological Survey (USGS) in relatively small study areas.

Strengths and Limitations of the Data

In recent years, population density surveys at the permanent study plots have not been conducted on a regular basis due to lack of funding. Prior to 1994, plots were surveyed at average intervals of four years. Between 1995 and 2001, surveys at the 15 baseline study plots were limited due to lack of federal funding. Since 1995 only five plots have been surveyed, two of which were conducted with funds from outside the USGS or the Bureau of Land Management (BLM). In 2002, the California Department of Fish and Game will support surveys of four plots through the USGS, and BLM plans to contribute funds for additional work. Valuable information is lost by the longer intervals, making it harder to understand the causes of disease and population changes (Berry, 1999).

References:

Berry, K.H. 2000. *Preliminary report on the spring survey of desert tortoises at the Goff's permanent plot and special project of effects of roads.* USGS, Riverside California.

Berry, K.H. 1999. *Preliminary Report from the 1999 Spring Survey of the Desert Tortoise Long-Term Study Plot in Chemehuevi Valley and Wash, California.* Unpublished report provided by the author, Station Manager of the USGS Western Ecological Research Center, Riverside, CA.

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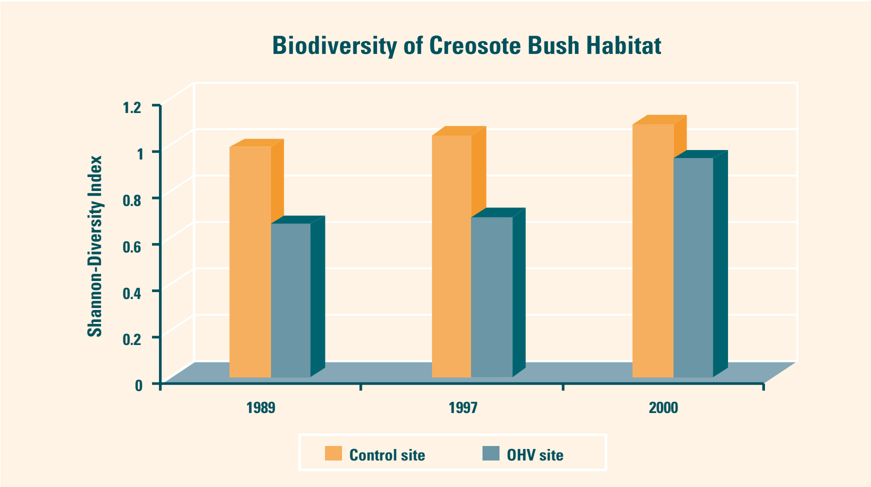
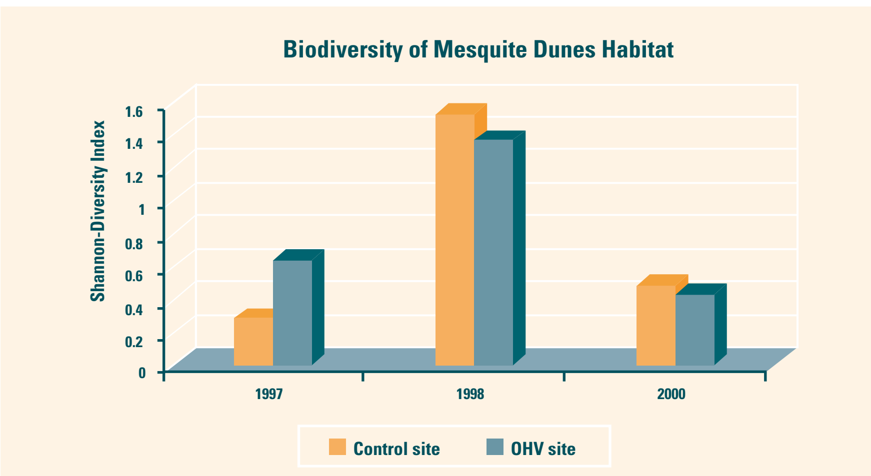
Impacts of Off-Highway Vehicles on the Desert





Type II

What is the indicator showing?

In creosote bush habitat, off-highway vehicle (OHV) use has decreased plant diversity. In contrast, in mesquite dunes habitat, plant species diversity is similar at the OHV and control study sites. Differences in moisture content of the soil and regeneration time of vegetation in the two habitats are some of the factors that contribute to this disparity.

Why is this indicator important?

The California Department of Parks and Recreation monitors the impact of off-highway vehicles (OHV) on vegetation and wildlife species diversity in all State Vehicular Recreation Areas (SVRA). In 1991, the Department of Parks and Recreation initiated a monitoring program to assess the impacts of OHVs on vegetation and animals (ohv.parks.ca.gov). The Shannon Diversity Index (SDI) is used to measure biodiversity by calculating the ratio of the number of each type of species relative to all species within the "monitored area." A higher Shannon's Diversity Index value indicates greater species diversity. Data are being collected on mammals, reptiles, and birds as well as vegetation. At present, there are sufficient data for interpretation only for vegetation. In future years, information on animals will be presented in an updated report.

What factors influence this indicator?

Off-road vehicle use is one of the major recreational activities in the deserts of California. In a number of different ways, OHVs can negatively impact the desert. OHV use can compact soil, damage or destroy plants, reduce water infiltration, increase wind and water erosion, and produce intense noise. OHVs are also one source of ambient nitrogen oxides, which have been correlated with increased soil nitrogen deposition and the accompanying increase in exotic plant species. All of these stressors have the potential to adversely affect the desert ecosystem. Since recovery from these impacts is much slower in the desert than elsewhere, it is important to detect changes as early as possible.

Comparison between the creosote bush and mesquite dune habitats suggests that OHVs may affect the former more than the latter. Three possibilities account for this disparity. First, there may be less wind scouring and desiccation in mesquite habitat, leading to higher moisture content of the soil. Higher moisture content facilitates growth of vegetation. Second, hardpan, hard compacted soil, is more prevalent in creosote bush habitat. It is more difficult for plants to become established in hardpan compared to other types of soils. Third, creosote bushes produce chemicals that can inhibit the growth of other nearby plants. These factors as well as others contribute to the poor ability of plants to regenerate in those OHV-areas dominated by creosote bush when compared to mesquite dunes. We need to gain a better understanding of the influence of these and other factors on the ability of vegetation to regenerate in OHV-use areas.

References:

California Department of Parks and Recreation, OHV website: ohv.parks.ca.gov

For information on the development of the U.S. Bureau of Land Management's new OHV plan to protect the environment, see their website: www.blm.gov/ohv.

An analysis of the plan by the Wilderness Society is posted at: www.wilderness.org/standbylands/orv/blm_strategy.htm.

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Type III

Distribution of Exotic Plants

Exotic plant species are spreading throughout the desert as a result of a variety of anthropogenic stressors. The extent of exotic plant species could be developed as an indicator for health of the desert ecosystem. The effects of exotic plant species on productivity and diversity of desert habitat are under study. Although the number of exotic plant species in the desert is relatively small compared to other regions of California, those that have become established present a threat to the structure and function of native desert plant communities. Research has shown that as the biomass and extent of exotic plants increase, the diversity of native plant species declines to the detriment of the wildlife that relies on the native species. In addition, increasing amounts of exotic annual plants create a wildfire hazard that did not exist prior to these plants becoming established in the desert. This is a significant problem since regeneration time in the desert is exceptionally slow.

Red brome, schismus, and filaree, all non-natives, now account for the majority of the annual plant biomass in many areas of the California Mojave Desert. Fires are more frequent where the biomass of red brome is high, and fires have become more frequent since the invasion of red brome into the Mojave Desert region (Kemp & Brooks, 1998).

At this time, there are no systematic regional data showing the extent of invasive plants in California deserts. Various research projects are underway to determine the extent and effects of exotic plant species. The U.S. Geological Survey (USGS) has a Southwest Exotic Plant Mapping Program for Arizona, New Mexico, and the Colorado Plateau portions of Utah and Colorado. This project is developing and distributing information on exotic plant species distributions. If extended to include the California desert, this program could provide data for an indicator of the extent of invasive plant species. (Contact: Dr. Kathryn Thomas, Ecologist, USGS Forest Resources Ecosystem Science Center, (520) 556-7466 x 235; kathryn_a_thomas@usgs.gov).

Reference:

Kemp, P.R. and M.L. Brooks, 1998. *Exotic Species of California*. Fremontia, 26:4.

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Indicators

Change in habitat quantity in rangelands and forests (Type I)

Change in forest canopy (Type I)

Pest and disease related mortality in forests (Type I)

Wildfires in forests and grasslands (Type I)

Sustainability of California's forests (Type I)

Issue 4: Health of Forests, Shrub Land, and Grassland (Terrestrial) Ecosystems

Sub-issue 4.1: Habitat quality and quantity

Terrestrial habitat components include the abundance and configuration of landscapes, the presence of natural structural elements, and the fertility of soil. These components define a habitat's ability to support biodiversity, productivity, and overall habitat quality. As habitats change, disturbances associated with air pollution, fire, flood, harvesting, and development result in changes to forest size, age, density, spatial arrangement of trees and openings, soil organic matter, and loss of structural components such as snags and downed logs.

Habitat loss from agricultural conversion and urbanization reduces the ability of ecosystems to provide food and cover to animals. Interruption of ecological processes is the precursor to reduction of long-term sustainability and biological diversity.

The indicators to evaluate the status of forest habitat are listed in the box above. Habitat quantity is a direct measure of total acreage in the state. One factor used to assess habitat quality is canopy cover. Pests, disease, and wildfires are the major stressors on the forests and their impacts are reflected in the indicators. Finally, the relationship between growth and harvest of trees is used to assess the sustainability of forest lands.

Indicators

Status of Northern Spotted Owl (Type II)

Status of amphibian populations (Type III)

Ozone injury to pine peedles (Type III)

Sub-issue 4.2: Loss of biodiversity

Biological diversity is defined as the variety and variability of living organisms and the ecological complexes in which they occur. The state's diverse topography, soils, geographic position, and climate contribute to a wide range of terrestrial habitats and plant and animal species, many of which are unique to California. Our rich resource base, pleasant climate, and economy have also attracted a large and growing population, impacting the state's biodiversity. The two major stressors on terrestrial biodiversity are a) conversion of habitat due to urban, suburban, and agricultural/forestry/range use, and b) introduction of non-native species. Conflicts between human activities and conservation of the state's biological wealth can be expected to escalate and will provide future conservation challenges.

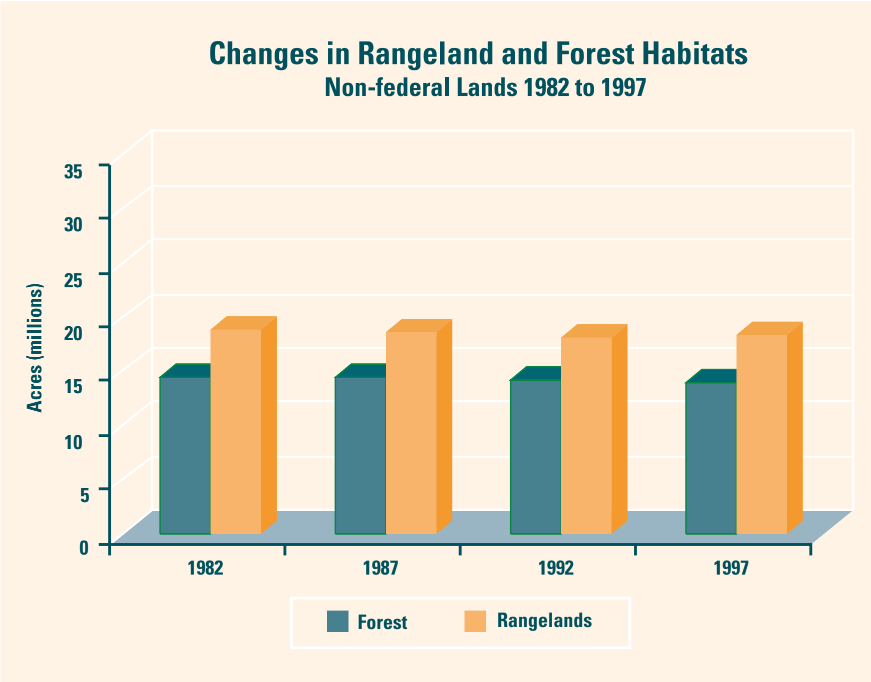
Spotted owl status was selected as an indicator of biodiversity because this owl is on the state and federal threatened and endangered species list and is highly sensitive to alterations in habitat. The status of amphibian populations is an issue of emerging concern due to widespread reports of deformities and declines in populations of frogs. Ozone effects on pine needles was also included as an indicator because it clearly links ambient air pollutants regulated by the state to damage of a valued natural resource.

Change in Habitat Quantity in Rangelands and Forests

Losses in acreage of rangeland and forest habitats from 1982 to 1997.

Type I

Level 6
Goal 4, 6



What is the indicator showing?

Approximately 1.2 million acres (from 33.4 million acres in 1982 to 33.2 million acres in 1997) of range and forest habitats on private land were converted to other uses or transferred to public ownership.

Why is this indicator important?

The indicator tracks private rangelands and forests to monitor changes in the loss of natural vegetation that exist on most range and forest lands. Compared to more intensive land uses (agriculture, urban), private range and forest systems contain a greater amount of natural vegetation, wildlife habitats, and less alterations of water quality.

What factors influence this indicator?

Private range and forest habitats decreased by approximately 1.2 million acres from 1982 to 1997 at an average rate of 79,000 acres per year. While some of this land went into federal ownership, the remainder of the total decrease represents a shift to residential uses, commercial development and irrigated agriculture. Several observations regarding the change in range and forest land area can be made:

- Over 930,000 acres of range and forest land were converted to "developed land" or "other rural land," categories which describe urbanization.

- 618,00 acres of private range and forest land were transferred to federal ownership, where the natural habitat characteristics of the land are likely maintained.

- Rangeland and agricultural land have had substantial exchanges during the period resulting in a net gain of over 365,000 acres of rangeland from agricultural land (Cropland and Pastureland).

Most of the changes within the private forest area measured by the National Resources Inventory (NRI) are outside of the productive forest land capable of being managed for timber production. While private productive timberlands represent about 25 percent the private rangeland and forest land base, only 10 percent of the annual loss comes from productive timberlands. Of the total annual loss of all range and forest area of 79,000 acres per year, productive timberlands losses average about 7,600 acres per year during the same period.

Technical Considerations:

Data Characteristics

Methods for data collection have been established since 1982 between the Natural Resources Conservation Service and Iowa State University. The National Resources Inventory is the source used to derive this indicator. This source uses a fixed plot point sampling system to revisit periodically the same site to monitor the status of the land base. The primary plot size is 160 acres with a sampling rate of approximately 2 to 6 percent of the sampling area.

Strengths and Limitations of the Data

Data used to construct this indicator are limited to the broad definitions of forest and rangelands provided by National Resources Inventory. Specific habitats within these broad categories are not discussed. Additionally, no information is publicly available to better identify lands at greatest risk for conversions.

References:

Natural Resources Conservation Service. *Summary Report, 1997 National Resources Inventory*. Revised December 2000. Posted at: www.nhq.nrcs.usda.gov/NRI/1997/summary_report/original/contents.html

Pacific Northwest Research Station, Forest Inventory and Analysis Program www.fs.fed.us/pnw/fia/

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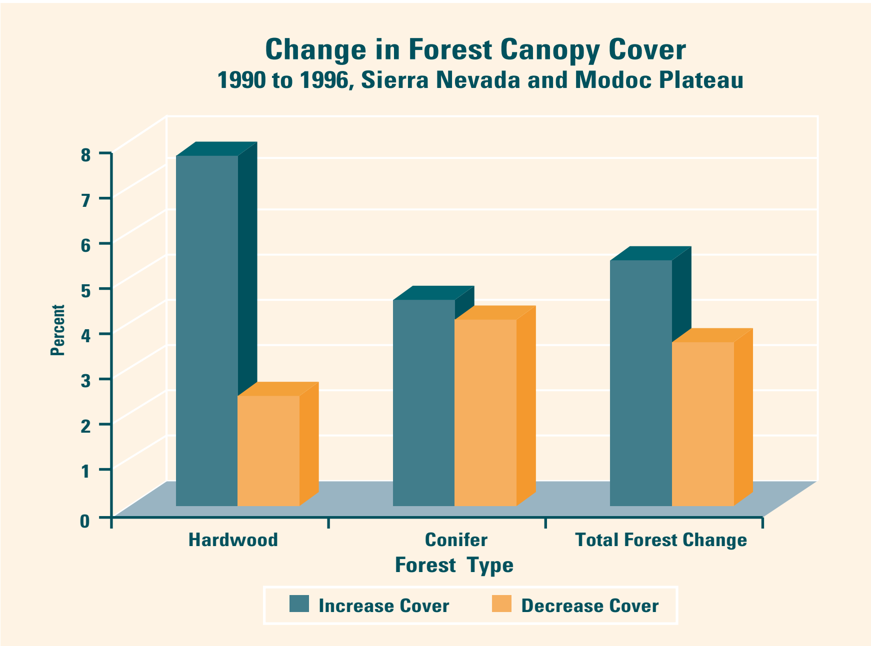
Change In Forest Canopy

Forest ecosystems show dynamic changes in canopy cover in the Sierra Nevada and Modoc Plateau from 1990 to 1996.

Type I

Level 6
Goal 6



What is the indicator showing?

Increases in canopy cover in two major California forest regions exceeded decreases in canopy cover. The increases are primarily due to regrowth of young forests. In contrast, decreases are occurring in forests of all ages, spanning the range from young to very old forests. The substantial increases in hardwood relative to conifer canopy cover are due to regrowth in past fire areas.

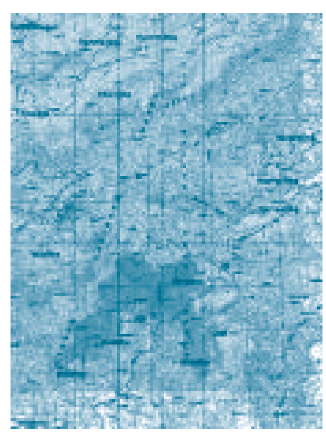
Why is the indicator important?

Forest cover, or the horizontal area that trees occupy, is both biologically important and affects human value of forest ecosystems. It describes the continuity and density of tree vegetation on the landscape. Alterations in forest cover changes the mix of age classes and can have both positive and negative effects on wildlife habitat, fire conditions, aesthetics, productive capacity, economic value and air quality change.

Forests are always in a dynamic state of change as younger trees grow to occupy gaps within forests. As forests grow, trees are lost due to mortality, fire, harvest, and development. Identifying the spatial patterns of these changes requires analysis of the change of canopy cover between two time periods. The figure illustrates a detailed map of changes developed from a comparison of two satellite images taken 5 years apart as part of a statewide assessment of changes in vegetation. This analysis accurately captures the area and causes of changes in total vegetative canopy cover, but not the changes in total biomass.

For the combined region encompassing the Sierra Nevada and the Modoc Plateau to the north, more than 90 percent of all forest areas showed no change in forest canopy between 1990 and 1996. Approximately five percent of the area showed an increase in canopy cover while another four percent showed a decrease.

Change in Forest Canopy Map

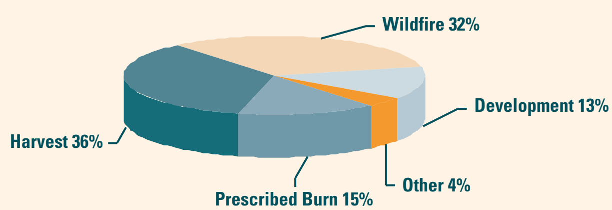


See full color map on page 257

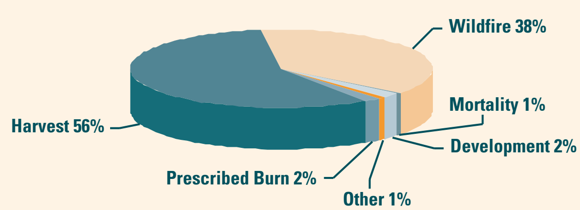
What factors influence this indicator?

On the 16.1 million acres of conifer and hardwood forests in these regions, increases in canopy coverage exceeded decreases in canopy coverage (875,000 vs. 582,000 acres) between 1990 and 1996. Increases are attributable to normal growth patterns or rapid regeneration after fires or harvesting in the previous period and are primarily found in small tree size classes. Decreased canopy cover is attributable to human intervention (harvesting and development) as well as natural events (wildfire and pest damage). With the exception of permanent land conversions, the re-growth of the forests through the sequence of seral stages will begin on these sites. The spatial identification of where these patterns are occurring allows for a more detailed analysis of what is driving these changes in forest seral stages in different areas around the state. See pie charts below:

Hardwood Forest Canopy Decreases by Cause
Modoc and Sierra Bioregions, 1990 to 1996



Conifer Forest Canopy Decreases by Cause
Modoc and Sierra Bioregions, 1990 to 1996



Lands that experienced large decreases in canopy cover (greater than 70 percent canopy cover reduction) are a particular concern. While a variety of mosaics of opening are sustainable, these types of decreases usually represent long-term or permanent shifts in habitat type (e.g., major fires that completely replace forests and development). More than 41,000 acres of conifer forests and 5000 acres of hardwood forests had large decreases in canopy cover.

Technical Considerations:

Data Characteristics

Multi-date Landsat TM imagery provides the base data. The data covers all major forests and rangelands (excluding desert) and monitors over 65 percent of the land base of the state. Three classes of vegetative change are assessed for increases and decreases: large, moderate and small. Additionally, a no-slight change class is monitored.

Strengths and Limitations of the Data

Data of this type have a number of important strengths. First, information can be particularly relevant for watershed analysis, where site-specific impact information is needed. Second, data are used to update existing vegetation maps and to re-inventory permanent plots. Third, with data being spatially available within Geographic Information Systems, they can be combined with other data sets to interpret forest conditions that influence ecosystem management decisions.

A limitation to the data is the accuracy of interpretation of change. Vegetation increases in hardwoods or conifer canopy do not always represent canopy change, as seasonal variation due to vegetation moisture content may give an inaccurate reading. Additionally, not all monitored areas are assessed for the cause(s) of change.

References:

Chris Fischer, GIS Analyst, Fire and Resource Assessment Program (FRAP), California Department of Forestry; Lisa Levien, Remote Sensing Specialist, USDA Forest Service Remote Sensing Laboratory.

Fire and Resource Assessment Program (FRAP), California Department of Forestry; frap.cdf.ca.gov/projects/land_cover/monitoring/index.html

USDA Forest Service Remote Sensing Laboratory. www.r5.fs.fed.us/fpm/index.htm

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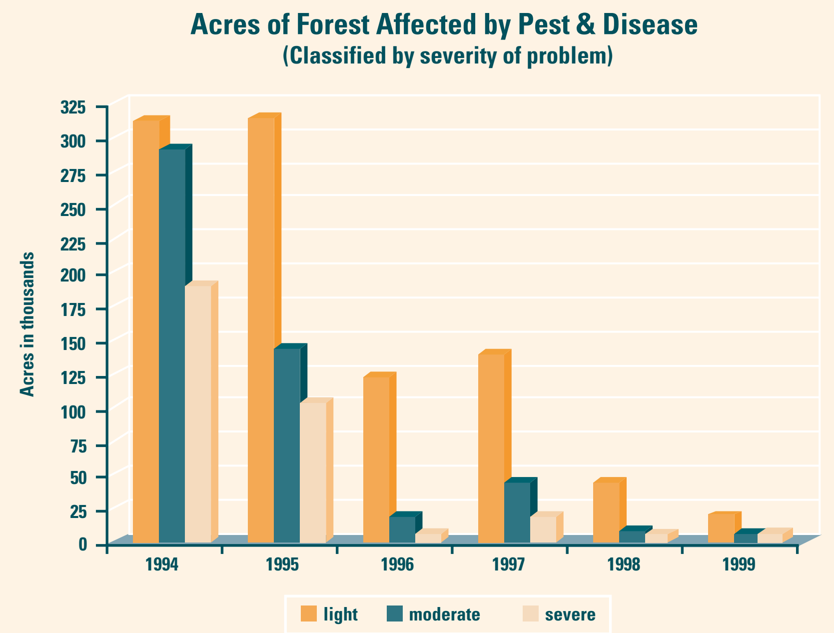
Type I

Level 6
Goal 4, 6

Pest And Disease Related Mortality In Forests

Tree mortality in California's public forests has been decreasing since 1994.



What is the indicator showing?

The acres of federal and adjacent private forest land where tree mortality has occurred have decreased from very high levels in 1994 to relatively low levels in 1999.

Why is this indicator important?

Forest insects and diseases often shape California's forests at basic levels with cyclical outbreaks. With historic information suggesting that mortality typically affects one percent of the forest land base annually, peak levels seen in 1994 affected nearly five percent of the surveyed forest land base. By 1999, mortality had dropped below the long-term average of one percent. The desired state of forest health, in relation to insects and disease, is the condition in which these agents do not seriously threaten ecosystem structure and function on a continuous basis. At low levels, insects and disease provide a necessary role through pollination, nutrient cycling and thinning of weakened and stressed trees. Fire suppression, grazing and logging activities have combined with natural ecosystem processes to create overly dense stands of trees and have altered the mix of vegetative species. This alteration of conditions has resulted in an increase in susceptibility to insects, disease and weather-induced stresses. Non-native pests also play a major role in altering conditions and contributing to forest mortality. These changes can reduce the quality of habitat for wildlife.

Statewide Mortality
1994-1999, Based on Aerial Surveys

See full color map on page 258

What factors influence this indicator?

Observable mortality in forest ecosystems is a cyclical event due to a combination of native pest agents, pollution, human management, wildfire, stand conditions, introduced pests and climatic conditions. The high levels of conifer mortality observed during the early 1990s have declined dramatically since 1994. The mortality was caused by bark and fir engraver beetles in concert with overstocked stand conditions, altered species compositions and the protracted drought between 1987 and 1991. Acres of mortality on surveyed forestlands dropped from 809,000 in 1994 to 33,000 in 1999. The damage during the late 1980s to 1994 represented a peak in the cyclical pattern of damage to California forests.

Technical Considerations:

Data Characteristics

The data are collected as part of the National Forest Health Monitoring Program, which is a cooperative state and federal program to annually survey for the conditions of the federal forests. Results summarized here are for the aerial survey portion of the monitoring program. Data collected from aerial surveys are further classified by the severity of change; the percent mortality is identified in polygons circle on a map. Mortality is then classified as lands with greater than 11 percent mortality (severe), 6-10 percent mortality (moderate), and 0-5 percent mortality (light). Over 80 percent of the observed mortality was in the light and moderate categories.

Strengths and Limitations of the Data

The aerial survey used to determine mortality was limited to national forest lands and other public lands. Private lands were not the major focus of this survey. Of the over 36 million acres of forest land base in the state, approximately 22.5 million acres were surveyed in 1999.

References:

California Forest Health, U.S.D.A.; Forest Health in the West Coast, Cooperative U.S.D.A. and Oregon Department of Forestry; Forest Pest Conditions in California, the Forest Pest Council.

Timber Resource Statistics for the Resource Areas of California, 1994 and 1997, Waddel and Bassest. PNW- RB 214, 220, 221, 222, 224. www.r5.fs.fed.us/fpm/fhp_doc.htm.

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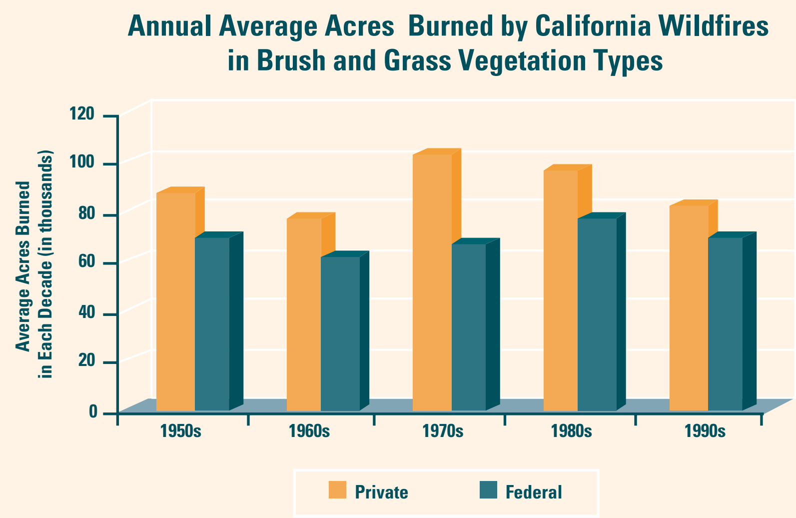
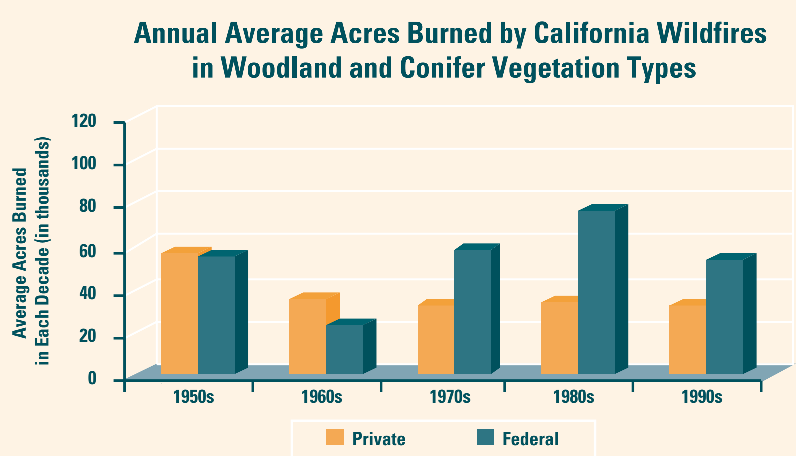
Type I

Level 6
Goal 6

Wildfires in Forests and Grasslands

Average acres burned by wildfires have been relatively constant except for an increasing trend on federal woodland and conifer forests.





What is this indicator showing?

Over five decades, wildfires in brush and grass types are more common than wildfire in forested areas.

Why is this indicator important?

By reviewing the number of acres burned over time, public land managers and persons concerned with natural resources on private lands may spot trends in the rate of wildfire occurrence. Such information may help these managers better understand the potential for impacts on ecosystem health. This indicator presents wildfire acreage information across different vegetation types and ownerships based on data collected from reports covering the period 1950 to 1997. As such, it is a broad and general indicator based the summary of past fire occurrences.

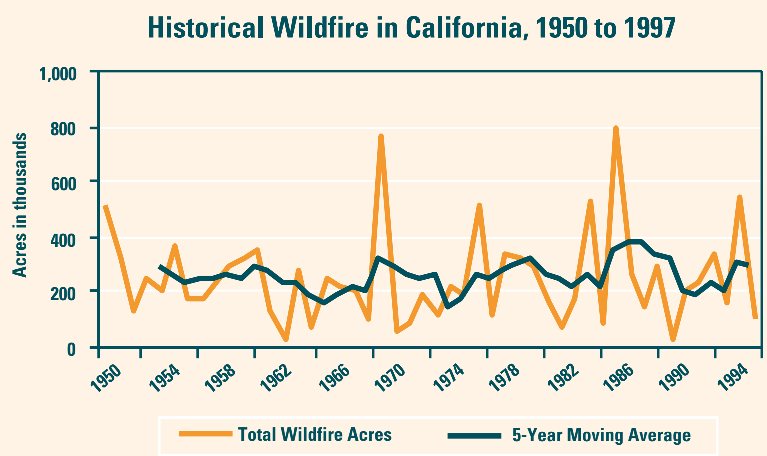
What factors influence this indicator?

Characteristics of individual fires, and their ecological and economic impact, depend on a number of factors including local fuel conditions, weather, topography, accessibility, availability of fire suppression resources, and suppression policies. The indicator does not discriminate as to the extent of area burned at ecologically destructive levels. Thus, we assume no systematic change in the average severity of fires (e.g., frequency of stand replacement). While wildland fire has been shaping California's landscapes for eons, the modern era has had substantially fewer fires compared to the period before European settlement. An average of approximately 200,000 acres burn each year, but year-to-year variability in acres burned is quite high. California's Mediterranean climate produces extensive areas with flammable vegetation. The dry summers drive down fuel moisture, and high winds can quickly turn an ignition into a serious fire leading to resource damage and loss of property, and sometimes lives as well.

Yet fire performs important work for ecological health. Ecologically, fire helps to shape the spatial structure and composition of vegetative cover, provides for nutrient cycling, and triggers changes needed to maintain natural ecosystem functions. Vegetation dynamics are significantly driven by an ecosystem's fire regime, which is the frequency and nature of fire in that system. Where modern era fire regimes are significantly different from those that the ecosystem evolved under, ecosystem health is jeopardized. An example of such a problem has occurred in forested types that evolved under frequent, low severity fire regimes. The modern era has extended fire frequencies allowing unnatural fuel accumulations that then result in high intensity fires, which burn through forest canopies and kill most or all trees, and cause high levels of soil damage. To enhance ecological health in these systems, the restoration of more frequent, lower intensity fires is needed.

Brush and grass ecosystems are experiencing more acreage burned by wildfire than conifer and woodland ecosystems, especially on private lands. The acreage of affected brush and grasslands is nearly the same as the forests, but brush and grass ecosystems generally burn more often and are predominantly in private ownership. They may have a higher propensity to burn because of the longer fire season in these areas, and because they are finer and more wind-exposed fuels that ignite and carry fire more readily. They also rapidly re-accumulate flammable fuels after a fire, and they have a greater spread rate, which challenges the initial fire suppression efforts.

Conifer and woodland ecosystems show a greater variation in area burned over time on public land as compared to private lands. This variation is probably a reflection of differences in the balance between natural forces and management efforts. Although stand-replacing fires occur on private as well as public lands, publicly-owned forests are often more remote and heavily wooded, with continuous canopy cover over large areas. Multiple lightning strikes across large expanses may quickly strain suppression resources available for initial attack. Accessibility problems and concerns about potential impacts from suppression resource often limit ground attack options. Thus, it is not surprising to see a greater volatility in the indicator as it applies to public lands.



The occurrence of years in which exceptionally large numbers of acres burn may be becoming more frequent. The wildfire pattern shown in the graph "Historical Wildfire In California, 1950 to 1997" suggests that since 1970, the number of fires that burned more than 500,000 acres appear to be increasing. Are these extreme fire seasons really becoming more frequent? Additional data may help clarify this important question.

Fire suppression efforts have changed ecosystem conditions and fire behavior. The fire perimeter data suggests that fire intervals (years between fires over a given area) have increased substantially throughout California woodland and conifer habitats. Historical fire intervals averaging ten years have now increased in some habitats to greater than 500 years. This increased interval is largely the result of fire suppression efforts. The ecological results of decreased fire frequency are:

- Composition shift to shade tolerant species
- Increased forest density (stocking)
- Increased susceptibility to beetle/insect infestation
- Increased surface and crown fuel hazard
- Increased tendency for the most devastating stand replacing fires and
- More receptive environments for invasive plant species in post fire habitats.

Additional information suggests that while the number of wildfires is within normal, cyclical ranges, the dollar values of assets destroyed by fire are rising significantly. Housing losses to wildfire have shown a large increase every decade over the last 50 years.

Technical Considerations:

Data Characteristics

The California Department of Forestry and Fire Protection (CDF), Fire and Resources Assessment Program (FRAP) and U.S. Forest Service (USFS) Region 5 Remote Sensing Lab are jointly developing a comprehensive fire perimeter Geographic Information System layer for public and private lands throughout the state.

The data initially included CDF fires 300 acres and greater in size and USFS fires ten acres and greater. The data includes most, but not all, fire perimeter data from other federal agencies (e.g., National Park Service, Bureau of Land Management, Bureau of Indian Affairs, Department of Defense) and local and county agencies. For official CDF fire statistics, refer to "Wildfire Activity Statistics", updated each year by CDF (Wildlife Activity Statistics, yearly). The analysis covers 47 years of fire data across 56 million acres of land. The earliest mapped fires recorded by CDF are from the year 1950; 1997 is the most recent year for which most areas in the state have data. Agricultural, desert, and urban areas are not included in the analysis. In addition, lands over 6,500 feet in altitude are excluded due the low prevalence of fires and the high proportion of areas that are either designated wilderness or non-roaded.

Strengths and Limitations of the Data

The fire perimeter data are continually under development and some fires may be missing altogether or have missing or incorrect attribute data.

References:

Fire and Resource Assessment Program (FRAP)
James Spero, james_spero@fire.ca.gov
Dave Sapsis, dave_sapsis@fire.ca.gov

Wildfire Activity Statistics, California Department of Forestry, published yearly.

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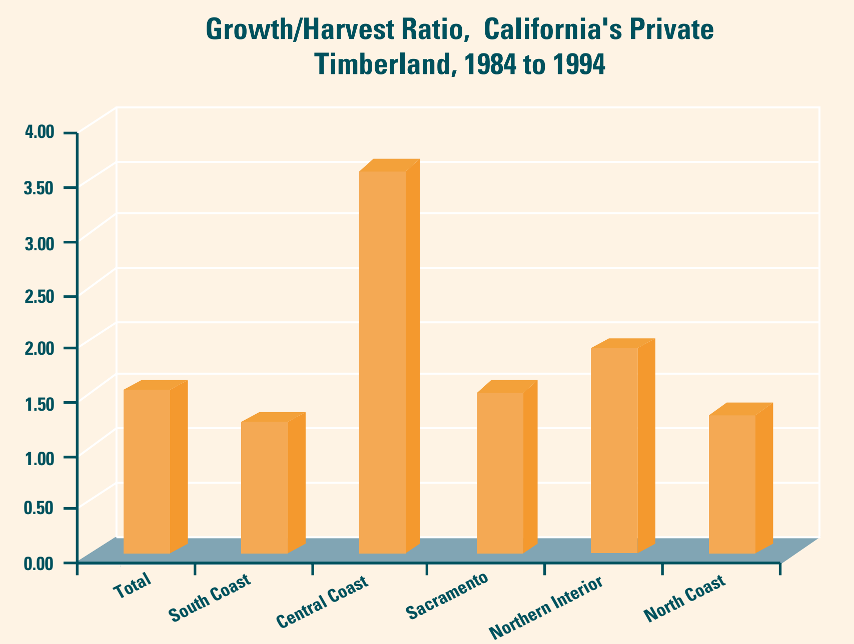
Type I

Level 4
Goal 6

Sustainability of California's forest

Growth on California's private timberlands exceeded harvest between 1984 and 1994.



What is the indicator showing?

On the State's private timberlands, growth is exceeding harvesting suggesting ecosystem processes are being maintained.

Why is this indicator important?

Long term sustainable forest management requires that forest growth exceed forest harvest, especially if there is a goal of increasing dense forest habitat. When growth exceeds harvest, several valuable ecological functions and habitat components of forested ecosystems are usually being sustained and often improved. Examples of wildlife habitat components that may be sustained include forest cover continuity and stands with larger trees. Additionally, watershed protection on a large scale will nearly always be greater if overall forest inventories are increasing. However, the relationship between increasing inventory and stable or better ecological conditions is not always proportional. Variation such as the spatial array of trees or the quantity and distribution of habitat elements in the forest (snags, down logs) is not captured by this indicator. Additionally, lack of harvesting can result in detrimental forest conditions, such as unnatural levels of fuel build-up in the absence of regular fire.

What factors influence this indicator?

This indicator compares the relationship of harvest to net growth of California's private forest lands in five different regions of the state. The indicator is developed by dividing total growth in millions of cubic feet (less total mortality) by the total cubic feet harvested.

Each region in the state has been classified as having productive land base on which growing and harvesting trees is a suitable practice. These lands are monitored every ten years to evaluate, among other things, tree growth, mortality (insect/disease/storm events), and the harvesting of trees. When comparing the results of these data in both conifer and hardwood forests, growth is 53 percent greater than harvest.

This indicator suggests that the state's forest ecosystems are producing more than the amount being harvested, indicating sustainable productivity conditions. Additionally, public lands with substantial forested ecosystems (Forest Service and National Parks) typically have very large growth levels that exceed harvest levels. If these data sets are combined, it is likely that forest growth substantially exceeds harvests in California.

Technical Considerations:

Data Characteristics

The data are collected as part of the U.S. Department of Agriculture, Forest Service (USFS), Pacific Northwest Research Station period forest inventory analysis. This is a national program conducted annually by the USFS and reported on 10-year intervals. The information is reported pursuant to the Forest and Rangeland Renewable Resource Research Act of 1978. Data are collected from fixed-plot ground-based sampling.

Strengths and Limitations of the Data

Additional information is available to describe growth/harvest on land owned by private groups (forest industry and other private owners). Certain regions, such as the North Coast where the majority of timberlands are found, may show different patterns of growth/harvest when separately reviewed. This indicator is only one of a suite which characterizes the conditions of ecosystem health of forest and rangeland habitats. When reviewed with other indicators, a more complete understanding of forest health conditions can be gained.

References:

Timber Resource Statistics for the Resource Areas of California, 1994 and 1997, Waddel and Bassest. PNW- RB 214, 220, 221, 222, 224.
www.fs.fed.us/pnw/fia/

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Type II

What is this indicator showing?

According to a recent survey by the U.S. Geological Survey (USGS), moderately sized populations of spotted owls still exist. The number of known or suspected pairs is 2,300 in California, 2,900 in Oregon, 860 in Washington, and 30 in British Columbia. Trends from models using research data indicate that populations are declining, primarily the result of low survival of adult female owls.

Reference:

USGS Status and Trends of the Nation's Biological Resources – Volume 2. Department of the Interior, Washington, D.C. 1998, pp 672-673.

Status of Northern Spotted Owl

Why is this indicator important?

In 1990, the federal government placed the northern spotted owl on the list of threatened species. This indicator is presented separately from the 'California Threatened and Endangered Species' indicator because it has been the centerpiece of debate regarding forest management on federal lands in the Pacific Northwest. The northern spotted owl inhabits the forests of the Pacific Coast region from southwestern British Columbia to central California and has an apparent preference for large tracts of old growth forest. Logging of old growth forests on federal land has been dramatically reduced in an effort to protect the spotted owl and its habitat, with severe economic consequences for timber-dependent communities in California, Oregon, and Washington.

What factors influence this indicator?

These are the only birds on the federal list of threatened and endangered species that occupy mature conifer forests. These forests are a dwindling resource, particularly coastal old-growth redwood forests. A federal study of species associated with old-growth forest listed 38 bird species. The U.S. Geological Survey (USGS) Breeding Bird survey shows downward trends for the population of 12 of these species; none of the 38 species shows an upward population trend.

More is known about the distribution and abundance of the spotted owl than about any other owl, but the status of the species is still hotly debated. In addition to habitat lost, population assessments are affected by weather, long-term population cycles, ratios of core to edge habitat, and survivorship to reproductive age. Further it appears that spotted owls respond differently to forest management practices in different regions of California and the Pacific Northwest. In some portions of northern California, for example, spotted owls are relatively common in redwood forests aged 60-100 years. However, few owls occur in such forests on the central Oregon Coast Range.

The productivity and occurrence of spotted owls also depends on the expanding population of barred owls. The range of the barred owl has been expanding from the eastern United States since the early 1900s. Now, the barred owl is found in northern California, the Pacific Northwest, and western Canada. Barred owls have invaded many forests that were previously occupied by spotted owls, and appear to displace resident spotted owls. In some cases, the two species interbreed. The long-term effects of the barred owl invasion will remain unclear for many decades.

Because spotted owls are a focus of debate about forest management practices, surveying and monitoring these owls will probably remain a high priority on federal and private forest lands. Although most current monitoring involves long-term studies of banded birds, other less costly methods (i.e., transect surveys) of population assessment are needed. Federal, state, and private organizations are involved in monitoring the spotted owl population. Accurate estimates of the population size are difficult to estimate due to their nocturnal nature and limited access to their remote habitat in rugged terrain.

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Status of Amphibian Populations

Type III

Why is this indicator important?

Declining amphibian populations are a concern both in California and globally (Wake 1991). Amphibian populations are declining in many parts of the world, and these declines have been characterized as particularly severe in California (Bradford, 1991). Among the species of greatest concern are the California Red-Legged Frog, which was listed as threatened by the U.S. Fish and Wildlife Service, and the Mountain Yellow-legged Frog *(Rana muscosa*), which is a California Species of Special Concern (Jennings, 1993). Recently, the Department of Fish and Game initiated a monitoring effort to produce baseline data on the status of amphibians in the Sierras and to evaluate how these populations are changing.

What factors influence this indicator?

Amphibians are sensitive to biological, physical, and chemical alterations in habitat. Amphibians absorb chemicals through their skin, making them sensitive to pesticides. There is also evidence that frog populations have declined as a result of the introduction of non-native predator sport fish that will eat small tadpoles (USEPA 1995). They can also be adversely affected by parasites. However, these one-time studies do not document the extent or pinpoint the cause(s) of amphibian population declines. Additional resources are needed to understand the causes of these mortalities, which might reflect significant alterations in forest ecosystems.

References:

Bradford, D.F. 1991. *Mass mortality and extinction in high elevation population of Rana mucscosa*. Journal of Herpetology Vol. 25, Issue 2, pp. 174-177.

Jennings, M.R., and M.P. Hayes, 1993. *Amphibian and Reptile Species of Special Concern in California. Final Report submitted to the California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, under Contract (8023).* 336 pp.

United States Environmental Protection Agency (USEPA). 1995. *Bioindicators of Assessing Ecological Integrity of Prairie Wetlands.* Report # EPA/600/R-96/082. 5.1 Ecological Significance. Washington, D.C.

Wake, D.B. (1991). *Declining amphibian populations*. Science 253 (5022): 860.

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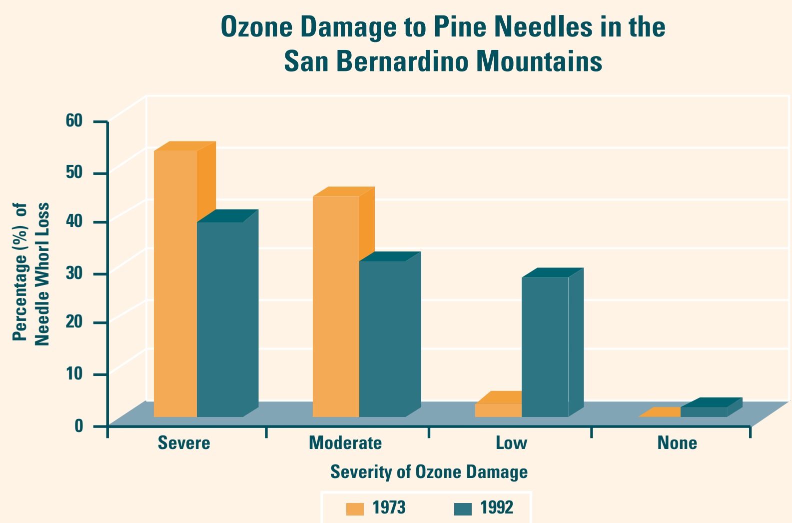
Type III

Ozone Injury to Pine Needles



What is the indicator showing?

Ozone damage causes needle yellowing (chlorotic mottle) and needle whorls to fall off of pine trees prematurely. When ambient ozone levels are high, a higher percentage of whorls are lost. When ozone levels are lower, there is less loss of whorls. The graph shows that as ozone levels in Southern California fell between 1973 and 1992, trees with high and moderate levels of needle loss declined; those with low levels or no loss increased.

Why is this indicator important?

Ozone is the predominant air pollution stressor of plants. It is an air pollutant that is known to damage plant cells and to reduce plant growth. Extensive damage to crops has been reported (McCool et al., 1986) and field studies document the presence of ozone injury on pines throughout California (Arbaugh et al., 1998). Injury to the needles of sensitive pine species, such as ponderosa and Jeffrey pine, has been documented in California since the 1950s (Richards et al., 1968). This information is useful because it clearly links an ambient air pollutant regulated by the state to damage to a valued natural resource, our forests. At present, there is no regular monitoring program to evaluate the effects of ozone on forests.

What factors influence this indicator?

There is strong scientific evidence concerning both the physiological mechanism of ozone-caused plant effects, and that the highest ambient concentrations of ozone in the U.S. occur in California (Miller and McBride, 1999). Over many decades, investigators have developed indicators of ozone injury, such as the severity of needle injury and the number of each year's needles that are retained. In the San Bernardino Mountains, pine injury plots were established in the 1970s that have been periodically resurveyed, most recently in 1997. For this region of the state, ozone air quality has improved in the last 30 years, and injury amounts have been stable or have decreased. Laboratory studies confirmed that the yellowing of pine needles observed in the mountains of southern California was caused by ambient ozone (Miller et al., 1969).

On the other hand, the pine injury plots established in the Sierra Nevada show a different trend. In central California, ambient ozone levels have increased in the past several decades, leading to higher amounts of ozone injury in Sierran forests. The data in the graph are from the San Bernardino study site; no data are shown from the Sierra Nevada research.

Technical Considerations:

Annual injury amounts vary from year to year, but injury amounts accumulate in older age classes of needles. Thus, assessments made at three to five year intervals are usually adequate for quantifying ozone impacts over time. In California, the two most widely used indices of ozone injury to pines are the Forest Pest Management (FPM) index (Pronos et al., 1978) and the Ozone Injury Index (OII) (Miller et al., 1996). The FPM index has been used by the U.S. Departments of Agriculture (Forest Service, USFS) and Interior (National Park Service) to survey tree injury in the Sierra Nevada. The OII has primarily been used by USFS to assess injury levels in the mountains of southern California (e.g., San Gabriel and San Bernardino Mountains), but has also been used in special studies conducted across the state (Arbaugh et al., 1998). Due to the use of one or the other index in most studies conducted in California, Arbaugh and co-workers (1998) developed an algorithm to calculate a FPM value from OII data. This allows comparisons to be made over a range of years and sites in the San Bernardino Mountains and Sierra Nevada.

The Air Resources Board (ARB) collects ambient ozone data at over 100 active monitoring sites across the state (ARB home page at www.arb.ca.gov), mostly in urban areas. The limited data for forest areas have been supplemented through studies using passive samplers (e.g., Arbaugh, 2000), to estimate ozone exposures in forests where monitors are not presently sited. Concurrent assessments of needle injury are made to develop exposure-response relationships, and in some cases, selected sites have been reassessed to investigate long-term trends. To our knowledge, there is no sustained funding for a program to assess needle injury from ozone. As the surveys are labor intensive, the USFS is only able to conduct surveys at irregular intervals. This is projected to continue to be the case unless sustained funding can be obtained. The San Bernardino Plots will be resurveyed at some point; and data from 1997-1998 may be available but are currently not in a form that is ready to present in a manner similar to the graph above. Many sets of measurements have been made in different forests, in different years. To make this data ready for use as a regional or statewide indicator an effort is needed to compile the existing data and to develop a systematic sampling plan.

References:

Arbaugh, M.J., 2000. *Ambient ozone patterns and ozone injury risk to ponderosa and Jeffrey pines in the Sierra Nevada*. Progress Report for February 17 through May 16, 2000, ARB Contract Number 98-305. 5 pp.

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Miller, P.R., J.R. Parmeter, Jr., B.H. Flick, and C.W. Martinez, 1969. *Ozone dosage response of ponderosa pine seedlings*. Journal of the Air Pollution Control Association, 19: 435-438.

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Pronos, J., D.R. Vogler, and R.S. Smith, 1978. *An Evaluation of Ozone Injury to Pines in the Southern Sierra Nevada*. Report 78-1. Pacific Southwest Region, USDA Forest Service, Forest Pest Management.

Richards, Sr. B.L., O.C. Taylor, and G.F. Edmunds, Jr., 1968. *Ozone needle mottle of pine in southern California*. Journal of the Air Pollution Control Association, 18: 73-77.

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Issue 5: Agroecosystem Health

Agroecosystems are domesticated ecosystems managed for the production of plants or animals. As with natural ecosystems, ecological resources and function are important for their sustainability. However, these ecosystems are substantially altered from their original state and the pressures they experience are often the result of agricultural practices.

Indicators

Conversion of Farmland into Urban and Other Uses (Type I)

Soil Salinity (Type II)

Sub-issues 5.1: Availability of natural resources

Productivity of agriculture is closely linked to two factors:

- The availability of land and its quality. Conversion of agricultural lands to residential, commercial, transportation or other non-agricultural uses increases pressure on the remaining land to produce an equivalent amount. This may increase the use of fertilizer, pesticides, and genetically engineered crops. It may also increase the pressure to convert coastal, forest, grassland and desert ecosystems to human use with attendant impacts on the integrity of those ecosystems and their biodiversity. Further, portions of agricultural land in the Central Valley are becoming unfit for production due to increased salt build-up, often caused by irrigation practices. Similar processes are occurring along the coast.

- The availability of water and its quality. Demand for water use comes from municipal/industrial, and environmental uses in addition to agricultural needs. Historically, agriculture has had an abundance of inexpensive water. In an effort to balance the needs of other users, this easy availability is unlikely to persist. New, more efficient methods of irrigation will be needed in the future. Freshwater quality is also a key resource. Salinity of the soil is linked to the quality of water. Sediments and contaminants leaving agricultural fields can also negatively affect the health of freshwater ecosystems.

Sub-issue 5.2: Positive and negative environmental impacts

Incorrect application or use of pesticides can lead to applicators, field workers, or those who live and work adjacent to areas where pesticides are applied being exposed to unsafe levels of chemicals. These factors, and the persistence of some pesticides in the environment, can lead to levels of chemicals that exceed regulatory standards. Such pesticide build-ups can negatively impact fish and wildlife.

Agriculture can exert positive environmental impacts as well. It can provide habitat for many species. Migratory birds, raptors, and some snakes use agricultural fields during certain times of the year.

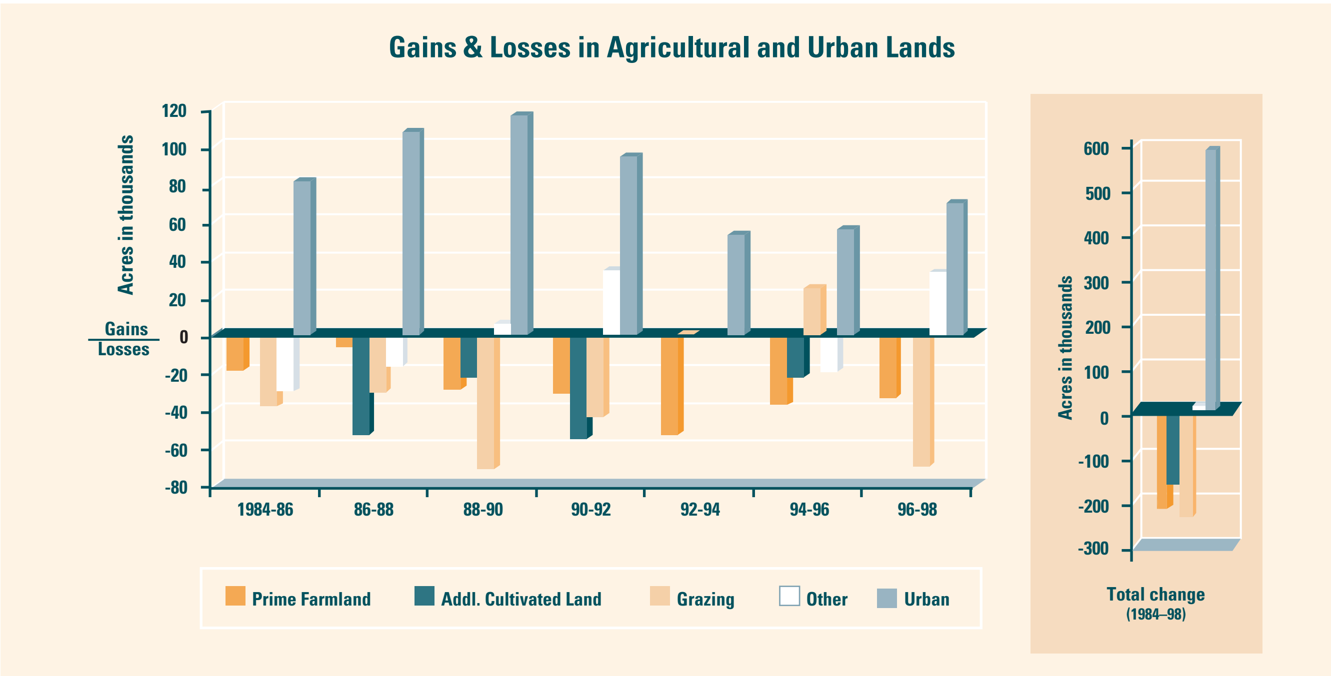
There are no indicators for this issue at present.

Conversion of Farmland to Urban and Other Uses

Farmland has been lost to urban development, removed from active use, or has been used for environmental restoration purposes.

Type I

Level 4
Goal 6



Why is this indicator important?

Between 1986 and 1998, approximately 5 percent of agricultural lands were removed from productive use. These lands were used for development, ecological restoration, or no longer cultivated for a variety of economic reasons. Between 1984 and 1998, the state's Farmland Mapping and Monitoring Program (FMMP) documented over 500,000 acres of new urban land, an area about the size of Alameda County in the San Francisco Bay Area.

California's rich land, water, and mild climate have allowed it to become the leading agricultural state in the country, and likely in the world (CDFA, 2001). The loss of prime agricultural land has substantial effects on the agricultural industry and the state's economy. Loss of agricultural lands forces farmers to intensify their farming methods to increase crop yields on less land. In some cases, only very large farming interests can afford to make such changes. The urbanization of farmland in mild coastal climates or on high-quality prime agricultural soils shifts farming onto poorer quality land, requiring greater levels of fertilizers to generate the same yields. In addition, conversions between agricultural uses, such as planting vineyards on grazing land, often entails practices such as deep-ripping, which alters the hydrology of the land, eliminating scarce freshwater wetlands and habitat for wildlife.

What is the indicator showing?

Prime farmland and grazing land have been the source of the majority of farmland conversions. "Additional cultivated land" includes non-prime agricultural land. "Other'" refers to low density rural residential, mined lands, and related uses.

Conversion of farmland also incurs human social costs. Because it is less expensive to develop on relatively flat farmland, many new, affordable residential areas are being built in rural areas that used to be far from major urban centers. This, in part, has led to longer and longer commutes; a phenomenon referred to as the "jobs-housing imbalance" (HCD, 2000). These changes have had significant effects on the social fabric of cities and the new suburbs as well as the economic and ecological health of rural areas.

What factors influence this indicator?

Population growth in California is the primary factor driving the conversion of agricultural land to residential use. However, the rate of conversion can be slowed by employing sound land use principles. By understanding the patterns of existing land use, the needs of the underlying ecosystems, and the demand for housing, planners and local governments can minimize the loss of agricultural land. Sound land use planning can avoid fragmenting agricultural and natural ecosystems into small, units that cannot function properly.

Technical Considerations:

Data Characteristics

Loss of farmland has been calculated in different ways, depending on how terms are defined, the level of detail, and the methodology used in studies. Some sources are solely statistical, being derived from landowner surveys (U.S. Census of Agriculture) or sample point assessment (U.S. Department of Agriculture (USDA) - Natural Resources Inventory). Others create continuous geographic coverages that are more useful for specific planning functions.

The Department of Conservation's Farmland Mapping and Monitoring Program (FMMP) updates its land use inventory every two years, based on photo interpretation and other sources, to report on agricultural conversion. The FMMP maps 90 percent of non-government land in California. The FMMP study area is 44.6 million acres as of 2000. It has increased from 30.3 million acres in the initial project year, 1984, as more soil surveys were completed by the USDA. Urban land is defined by FMMP as having a density of one building or more per 1.5 acres. Agricultural land is differentiated by irrigation status and soil quality, hence it includes both land use and land capability components.

Other programs that conduct land use mapping on a regular or occasional basis include the Forest and Rangeland Assessment Program (FRAP) of the Department of Forestry and Fire Protection, and the Land Use Section of the Department of Water Resources (DWR). FRAP estimates urbanization and sources of converted land. They categorize land as "urban" when there is one building per 20 acres in order to account for the impacts of roads and other

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American Farmland Trust (AFT), 1986. *Eroding Choices, Emerging Issues*. www.farmland.org

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California Department of Conservation, Farmland Mapping and Monitoring Program (FMMP), 2000. *California Farmland Conversion Report, 1996-98*. www.consrv.ca.gov/dlrp/fmmp.

California Department of Housing and Community Development (HCD), year 2000 Chaptered Bills, AB 2054 (Torlakson) housing.hcd.ca.gov/leg/2000Chaptered Bills.html
Housing Elements, Land Use and Planning

Kuminoff, N.V., A.D. Sokolow, and D.A. Sumner. 2001. *Farmland conversion: perceptions and realities*. Agricultural Issues Center, University of California. aic.ucdavis.edu/pub/briefs/brief16.pdf

infrastructure and household pets on natural communities. Satellite image classification is combined with data from other sources to determine change. Like FMMP, DWR relies on aerial photo interpretation, with a greater level of detail but lower frequency of mapping (6-8 year update cycle).

Strengths and Limitations of the Data

Gaps in statewide coverage, regional variations, and definitional differences among existing data sources will need to be addressed to determine specifically what should be measured as an indicator on the status of agricultural ecosystem health. Additional analysis will be provided in future EPIC reports.

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Soil Salinity

Type II

Why is this indicator important?

Approximately 30 percent of California's agricultural lands have a salinity problem (Tanji, 2001). The major problem occurs in the San Joaquin Valley, with secondary problems in the Imperial and Sacramento valleys. The quality of the soil plays an important role in the health and sustainability of California agriculture. Soil salinity refers to the amount of salts mixed in the soil. Saline soils impairs the growth of most crop plants. In California, 4.5 million acres of irrigated cropland, primarily on the west side of the San Joaquin Valley, are affected by saline soils or saline irrigation water. At present, data exist on soil salinity; however, additional work is needed before the data can be presented in a quantitative form.

What factors influence this indicator?

Soils from the San Joaquin Valley and other regions become saline because the water used for irrigation contains high amounts of dissolved salts. Since plants take up water, but not salts, the salts remain behind, increasing the salinity of the soil. Additional sources of salts include animal manure, biosolids, and gypsum – all routinely used in agriculture. Compounding the matter is the re-use of irrigation drainage water. In an effort to conserve water, some farmers collect drainage water after it has been used to irrigate crops. Drainage water contains higher amounts of salts than river water.

To improve the quality of the San Joaquin, Imperial, and Sacramento Valleys' soil for crops, water must be used to literally wash away the salts. This leachate water then must then be drained to evaporation ponds, or to the ocean, rather than reapplied to cropland.

Technical Considerations

Data on soil salinity is compiled by the U.S. Department of Agriculture, Natural Resources Conservation Service (USDA, 1992). This information will be reviewed and compiled by EPIC staff for future reports.

References:

Tanji, K. K. 2001. *Are salinity and trace elements a problem in irrigated California land?* California Agriculture (submitted).

National Resources Conservation Service, U.S. Department of Agriculture, 1992. *Salinity levels in the United States*. www.nrcs.usda.gov.

Additional information can be found at the Kearney Foundation Web site: www.cnr.berkeley.edu/~gsposito/Kearney.

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Indicator

Urban tree canopy (Type III)

Issue 5: Urban Ecosystems

Urban ecosystems have been almost completely transformed for human purposes, thus the pressures and concomitant effects on the urban environment are primarily judged in terms of their human impacts. Air quality, water quality, and the management of discarded material are a few of the issues important in urban ecosystems. These issues are covered in other sections of this report.

Sustainability issues are the focus of this section. The balance sought in urban ecosystems is one that provides a pleasant environment for humans, maintains some integrity of the natural landscape for wildlife, and minimizes the use and disposal of natural resources. Today, in particular, the size of the "energy-use footprint" is especially important in California. A variety of sustainability and quality of life issues have been identified by those working on the EPIC project and are put forth at this time to indicate our intention in the future to address these concerns:

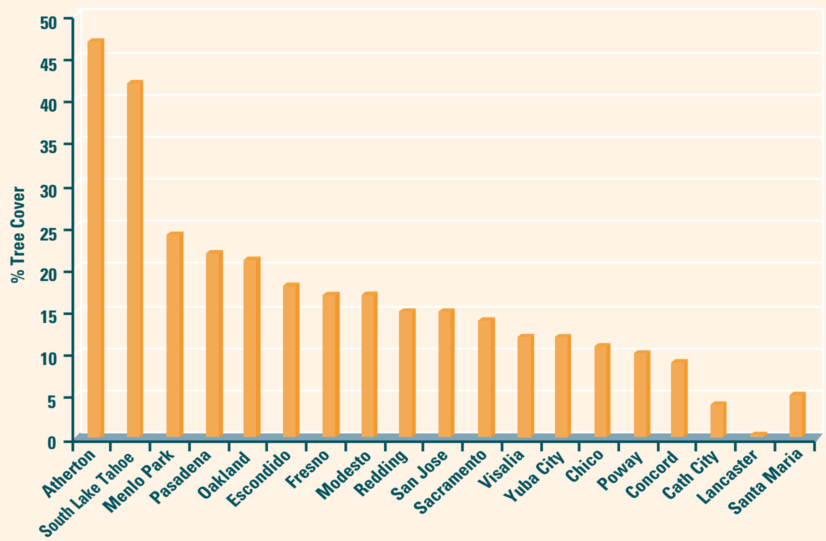
- Recreation availability and environmental impacts
- Employment opportunities in communities that have traditionally extracted natural resources
- Impacts of technology, such as genetic research, on productivity and ecological health
- Quality of living space and lifestyle
- Civic engagement in conservancies, restoration, and re-vegetation
- Regional planning and resource management related to natural resource protection
- Population growth and settlement patterns, including urban sprawl

Developing a group of urban ecosystem indicators to address these complex issues is beyond the scope of this first EPIC report. In the future, however, indicators will be developed to examine the issues identified above. For this report, one integrative indicator was selected, urban tree canopy. There is particular interest in this indicator at this time because tree canopy not only provides a pleasant environment for people and habitat for urban wildlife, but it can also reduce energy consumption by providing shade for homes and apartments and minimizing temperature increases associated with concrete roads and sidewalks.

Urban Tree Canopy

Type III

Tree Cover in Various California Cities



What is the indicator showing?

Tree cover in a selected group of California cities ranges from less than 1 percent (Lancaster, in the desert) to over 45 percent (Atherton, in the San Francisco Bay Area).

Why is this indicator important?

Urban ecosystems are where the majority of California's population lives and works. While the quality of urban ecosystems is based on a suite of parameters such as water quality, air quality, energy use, and traffic congestion, aesthetic factors are also important to urban quality. For example, several authors have identified the extent and variation of tree cover in urban areas of California as a measure of the importance placed on natural amenities. Urban tree cover provides insight into local land use and urban aesthetics, and serves as a basis for adapting future land use plans to optimize the beneficial aspects of tree cover. In addition, urban tree cover has been associated with a number of unquantified benefits, including removal of ambient air pollutants, removal of greenhouse gases, and reduction in energy/electricity use (Huang, et al., 1990; Nowak, 1994; Rowntree and Nowak, 1991).

What factors influence this indicator?

Urban tree cover in the U.S. ranges from 0.4 percent in Lancaster, California, to 55 percent in Baton Rouge, Louisiana (Nowak et al., 1996). In this study, surrounding natural environment and land use were the two main factors governing the extent of tree cover in urban areas. Cities established on forest land typically had greater tree cover than those on desert land (e.g., Lancaster). Moreover, land use plans that included areas set aside for greenspaces or parks had more tree cover than those that did not expressly incorporate space for vegetation. At present, the establishment and maintenance of urban forests is of concern to decision-makers who recognize the benefits they provide. These benefits include reduced energy use, habitat for birds, and pleasant aesthetics, to name a few. The benefits of tree cover in desert cities is a question that has important economic and natural resource implications. As urban development is projected to increase in the state, urban tree canopy is an important element that must be considered as part of regional planning.

Technical Considerations:

Various measures are used to describe urban tree cover (e.g., percent tree cover, total greenspace, canopy greenspace)(Nowak et al., 1996). Data of this kind are collected in large metropolitan areas by the USDA Forest Service; less labor-intensive measures of tree cover such as the presence/absence of tree planting ordinances, budget allocations for tree maintenance, or numbers of tree planting programs may be more available for medium-to-small urban areas.

Nowak et al. (1996) list four methods for estimating urban tree cover from aerial photographs — crown cover scale, transect method, dot method, and scanning method. Assuming that the required services and meta-data for interpretation of aerial photographs can be enlisted and obtained, estimating tree cover by any of the above four methods would provide reliable information. Standard statistical analysis could then be applied to distinguish differences among cities of different sizes, land-use types, etc.

The manuscript by Nowak et al. (1996) lists tree cover indices from 16-cities in California, primarily from unpublished data from the USDA Forest Service. It is not known how many other unpublished data sets are available or what data can be obtained from other published reports to establish trends for urban tree cover.

References:

Huang Y.J., H. Akbari, and H. Taha, 1990. *The wind-shielding and shading effects of trees on residential heating and cooling requirements*. ASHRAE Trans., 96: 1403-1411 (Original not seen)

Nowak D.J., 1994. *Air pollution removal by Chicago's urban forest*. In: EG McPherson, DJ Nowak, and RA Rowntree (Eds). Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. USDA Forest Service, General Technical Report NE-186, p. 63-81.

Nowak D.J., R.A. Rowntree, E.G. McPherson, S.M. Sisinni, E.R. Kerkmann, and J.C. Stevens, 1996. *Measuring and analyzing urban tree cover*. Landscape and Urban Planning, 36: 49-57.

Rowntree R.A. and D.J. Nowak, 1991. *Quantifying the role of urban forests in removing atmospheric carbon dioxide*. Journal of Arboriculture, 17: 269-275. (Original not seen)

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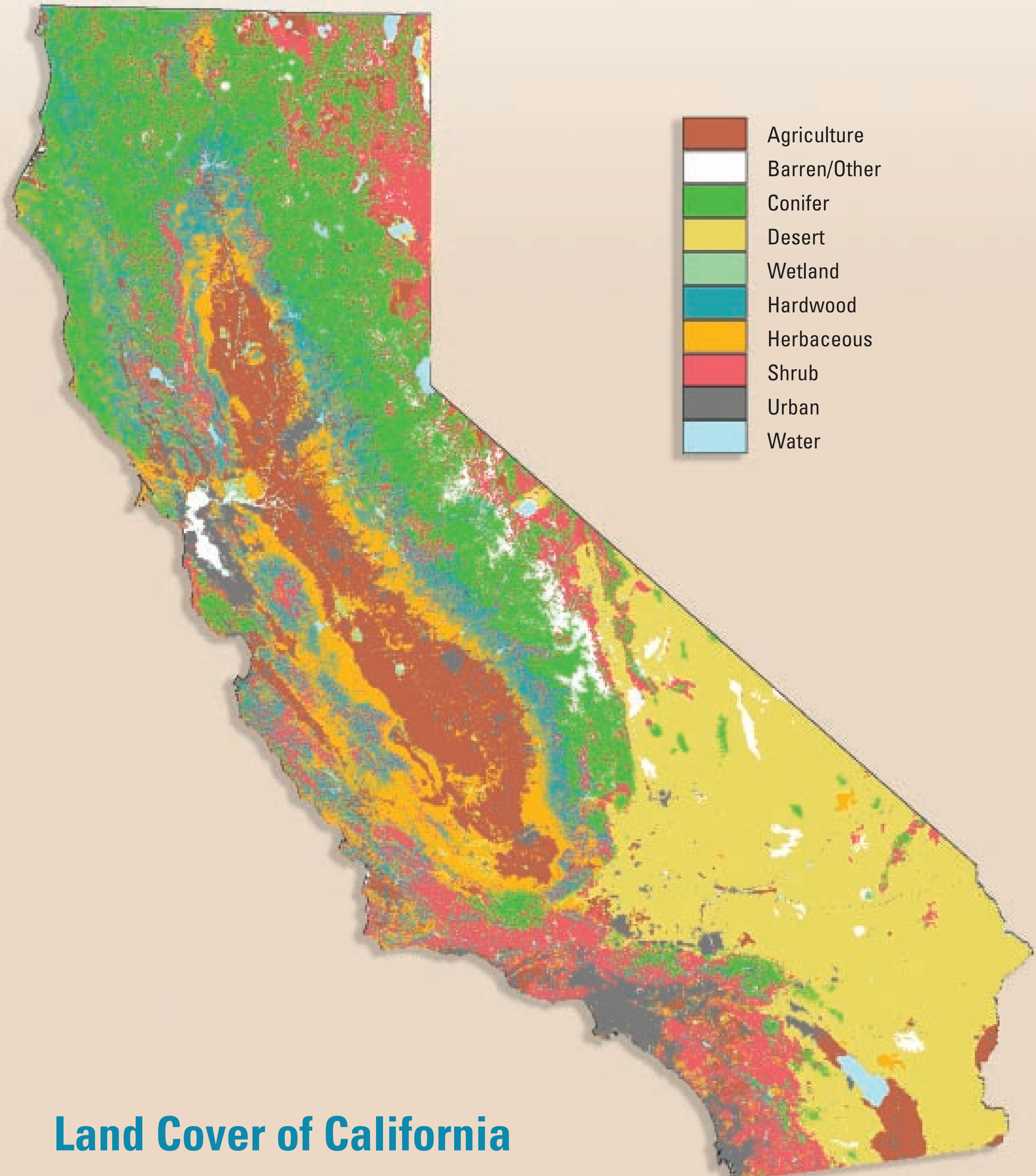
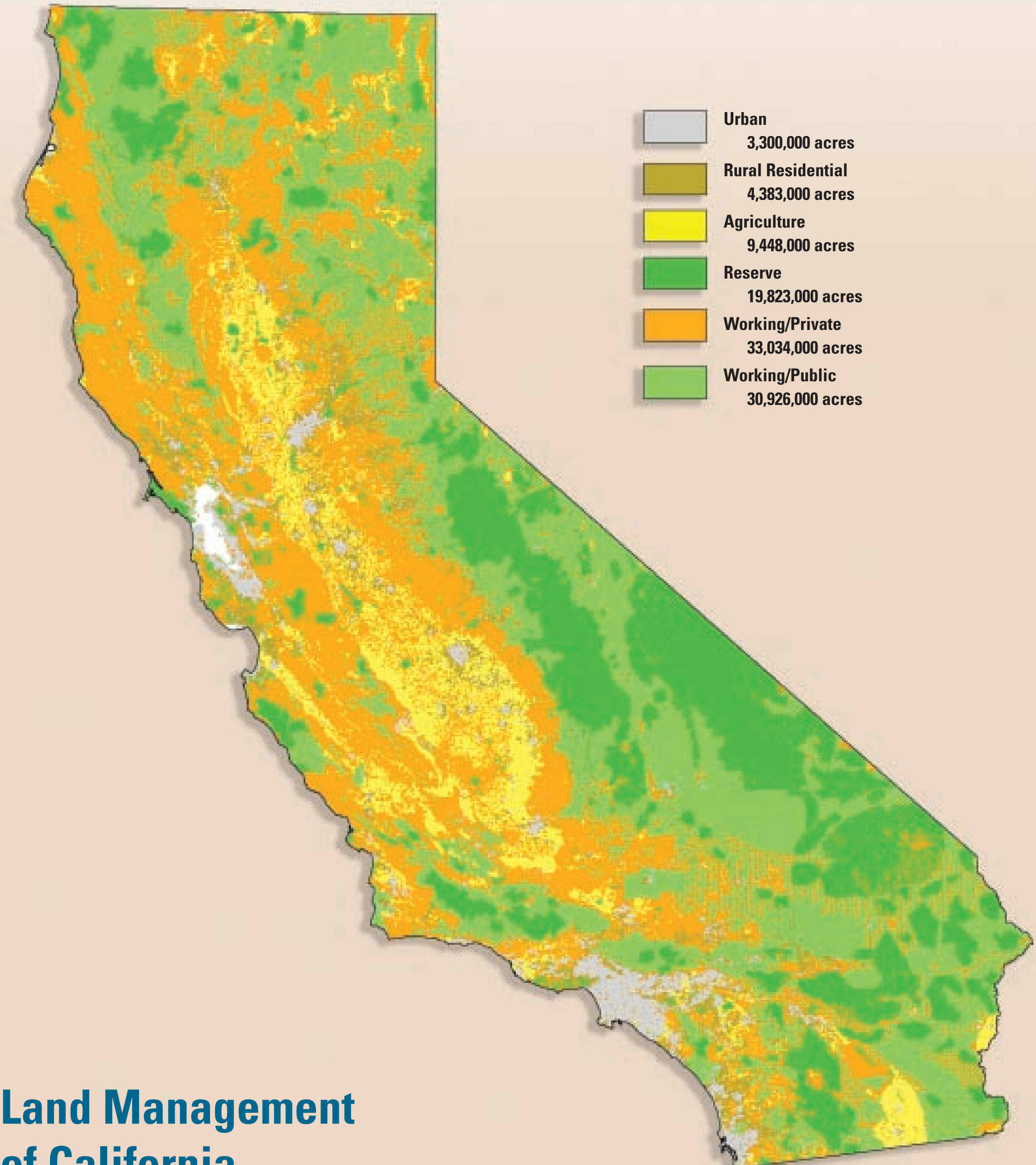


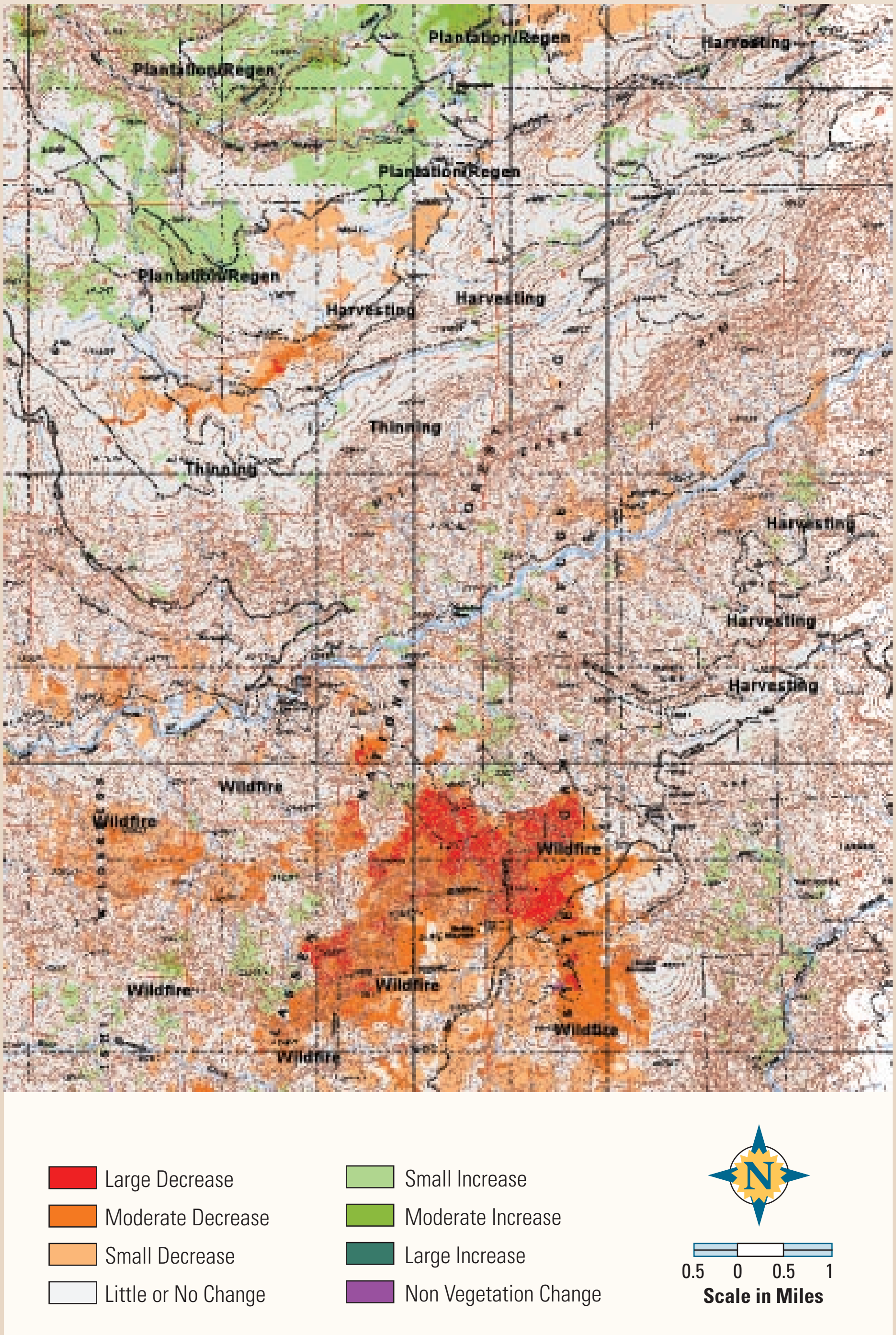
Land Cover of California



Land Management of California

Change in Forest Canopy Map

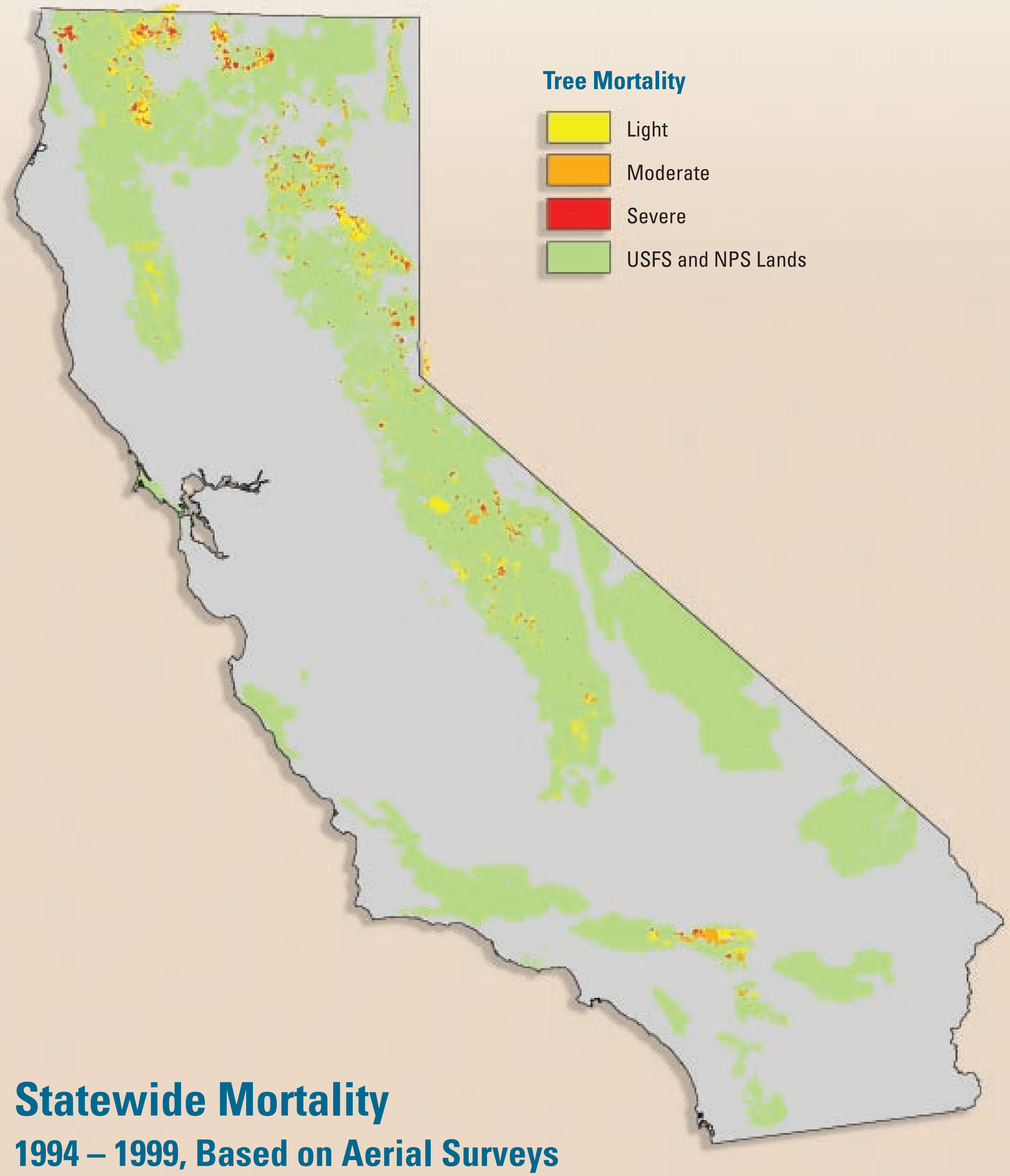
Portion of change map with verified cause in the Barkley Mountain quadrangle, Lassen National Forest, California



Forests are always in a dynamic state of change as younger trees grow to occupy gaps within forests. As forests grow, trees are lost due to mortality, fire, harvest, and development. Identifying the spatial patterns of these changes requires analysis of the change of canopy cover between two time periods.

The figure below illustrates a detailed map of changes developed from a comparison of two satellite images taken 5 years apart as part of a statewide assessment of changes in vegetation. This analysis accurately captures the area and causes of changes in total vegetative canopy cover, but not the changes in total biomass.

For the combined region encompassing the Sierra Nevada and the Modoc Plateau to the north, more than 90 percent of all forest areas showed no change in forest canopy between 1990 and 1996. Approximately five percent of the area showed an increase in canopy cover while another four percent showed a decrease.

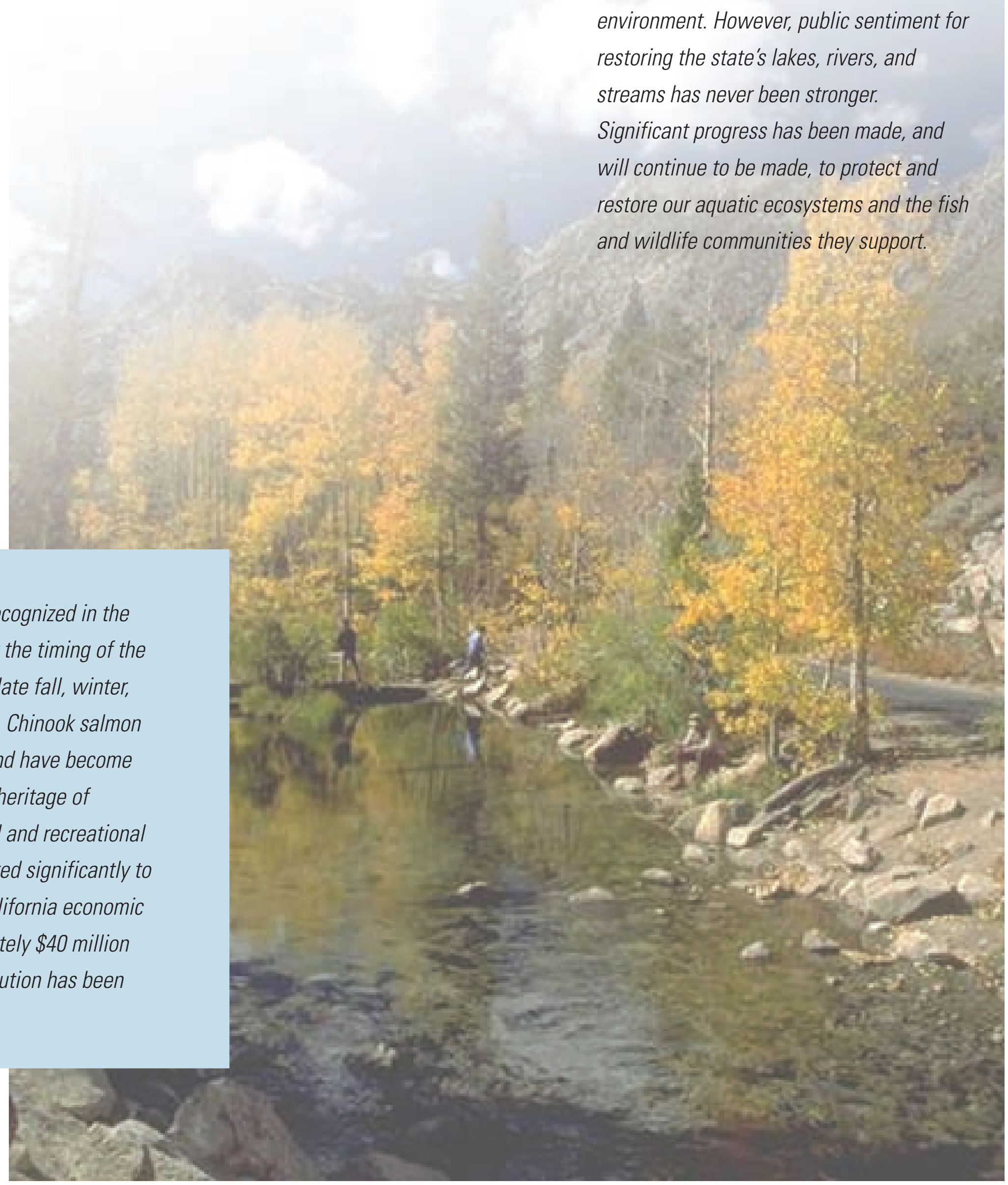


Statewide Mortality

1994 – 1999, Based on Aerial Surveys

Aquatic Ecosystems

The health of California's aquatic ecosystems has been significantly degraded over the past 150 years due to major land and water development activities. The decline in California's chinook salmon populations is an indicator of the degraded health of the aquatic environment. However, public sentiment for restoring the state's lakes, rivers, and streams has never been stronger. Significant progress has been made, and will continue to be made, to protect and restore our aquatic ecosystems and the fish and wildlife communities they support.



Four chinook salmon runs are recognized in the Central Valley, differentiated by the timing of the adult spawning migration (fall, late fall, winter, and spring-run chinook salmon). Chinook salmon have been historically valued and have become part of the cultural and natural heritage of northern California. Commercial and recreational fishing for salmon has contributed significantly to the economy. The estimated California economic impact for 2000 was approximately $40 million dollars. Historically, this contribution has been much greater.

Desert Ecosystems

The U.S. government treats the desert tortoise as an indicator to measure the health and well being of the desert ecosystem.

Mona Bourell, California Academy of Sciences

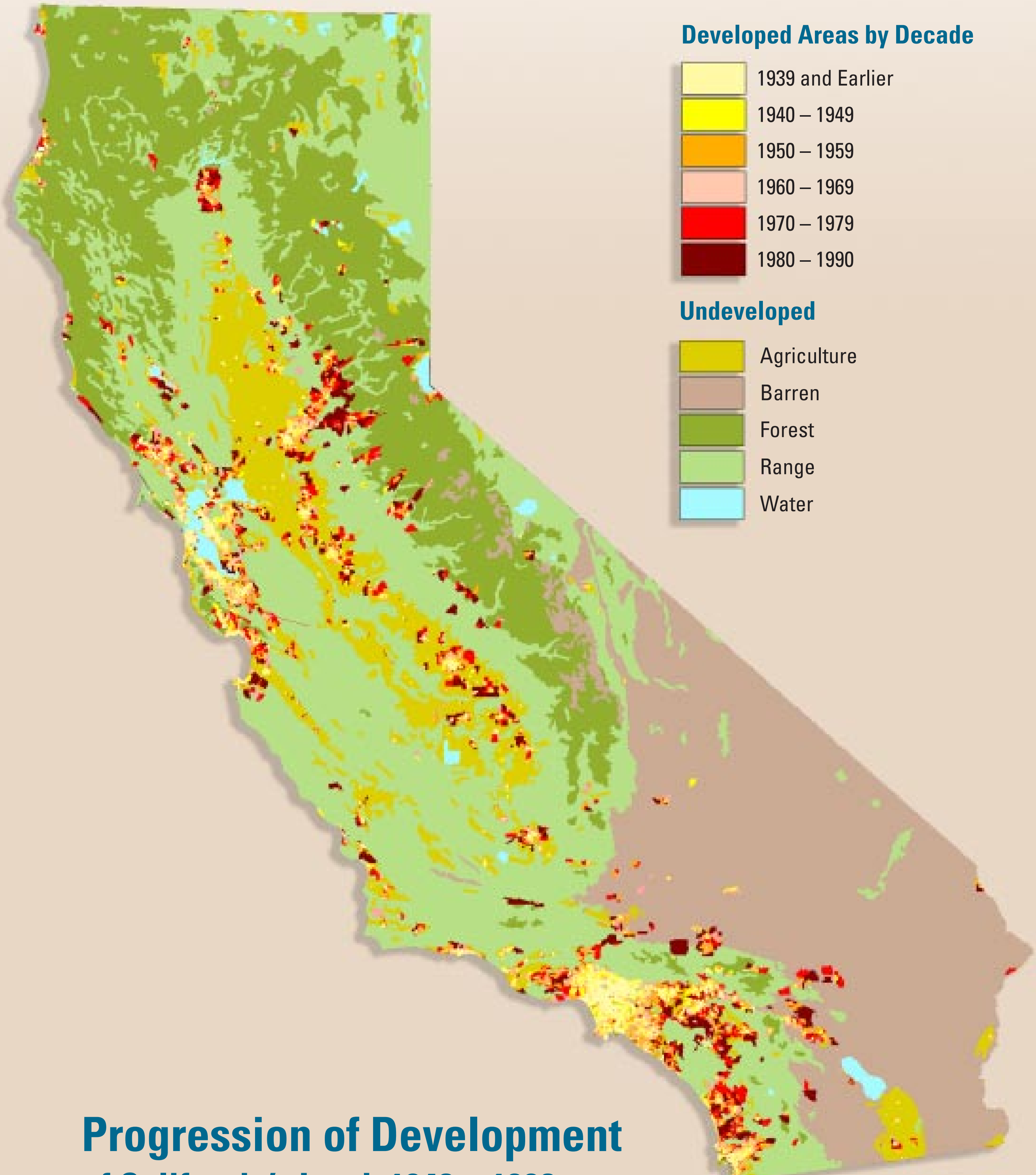
The desert tortoise population has declined dramatically because of human and disease-induced mortality, as well as destruction, degradation, and fragmentation of habitat. There are no stable or increasing populations in "critical habitats" in California, the 4.75 million acres of land designated by the U.S. Fish and Wildlife Service as critical for the recovery of the tortoise. The 2002 census recently completed in established study plots showed a continued downward population trend.

Forest, Shrub Land and Grassland Ecosystems

J & K Hollingsworth, USFWS

In 1990, the federal government placed the northern spotted owl on the list of threatened species. The northern spotted owl inhabits the forests of the Pacific Coast region from southwestern British Columbia to central California and has an apparent preference for large tracts of old growth forest.

California's forests, shrub lands and grasslands cover over 56 million acres. These lands have diverse wildlife habitats and tremendous biodiversity. Many of these lands are in a period of recovery in terms of ecological integrity after decades of use. Conversion to other land uses such as residential and commercial development are slightly decreasing the total area, especially near major metropolitan areas. Conserving the health of these ecosystems by protecting vital habitats, managing for appropriate levels of use, and restoring ecosystem functions while enabling economic growth will remain a challenge for California in the future.



Progression of Development
of California's Land, 1940 – 1990